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[SENATE.]

[386]

I. C. Russell
U.S.G.S.

A REPORT

TO THE

NAVY DEPARTMENT OF THE UNITED STATES,

ON

AMERICAN COALS

APPLICABLE

TO STEAM NAVIGATION, AND TO OTHER PURPOSES.

BY WALTER R. JOHNSON.

WASHINGTON:
PRINTED BY GALES AND SEATON.
1844.

ERRATA.

At page 35, line 16, for "*steady pressure*," read *steady action*.
44, at the 31st line of deductions, for 238°.47, read 230°.47.
A few verbal errors of less note will readily be corrected by the reader.

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PRELIMINARY REPORT

OF

EXPERIMENTS ON THE EVAPORATIVE POWER

AND

OTHER PROPERTIES

OF

AMERICAN COALS.

NAVY YARD,
Washington, November 28, 1843.

SIR: I have the honor to report that the experiments on the evaporative power of different coals, which have, for some time past, been carried on at this place, were concluded on the 18th instant. The examination of the other properties of the same materials, by such practical tests as can be here applied, is rapidly approaching its termination. The chemical analyses of some of the varieties hitherto operated on are yet to be performed. The large mass of facts collected during this research, referring to numerous points, and all of which are important to a full comprehension of the subject, is undergoing the examination and comparison which will enable me to present, in a final report, the respective and comparative values of the several kinds of coal for the different purposes for which fuel is employed.

A few weeks must unavoidably elapse before all these materials can be reduced to the required form, and furnished with the necessary drawings and illustrations. In the mean time, I beg leave to offer in this preliminary report some general statements relative to the origin, purposes, extent, and character of the researches which have been undertaken, and the nature of the results to be deduced from them.

The inquiry, now nearly completed, was instituted by your immediate predecessor, the Hon. A. P. Upshur, primarily on account of the difficulty which had been experienced, and the complaints which had been made, relative to the qualities of the coals procured for the naval service. It had been found that articles furnished to the Government at full prices, did not answer the expectations of those concerned in their consumption. While paying the highest prices for fuel, the efficiency of our steam vessels was sometimes impaired by its inferior quality, and the large amount of its impurity. Some few experiments on the subject had previously been made under authority of naval officers, but with means and appliances little calculated to afford the desired information.

It was evident that while securing the primary object—that of increasing the efficiency of the navy—the investigation must inevitably exercise a salutary influence on other branches of public defence, and be more or less felt in many important national interests. The possession, by any country, of a resource so important as extensive deposites of mineral fuel, may be justly regarded as an object of pride and pleasure, not less than one of universal *interest*. In some countries of Europe, it is well known, all mines belong to the public domain, even when found under a soil which is private property. Hence they are developed with the best resources of science, managed under the authority of special laws, and husbanded with the greatest care, to prevent unnecessary deterioration and waste. The Government of the United States, though not possessing this direct interest of proprietorship in mines, has still such a stake in the value of their resources, and the prosperity of citizens more immediately concerned in making them available, that the least which could reasonably be expected of it, is, to aid in some measure in ascertaining their true value. The department accordingly issued, about the middle of April, 1842, a notice, inviting the proprietors of mines, and others interested in the mining and sale of coals, to forward to this place, at their own charge, samples of their respective materials—engaging, on its part, to cause the same to be fully and impartially tested.

The question of the value of coals for the purpose of generating steam is, of course, mainly dependent on their heating power; that is, on the weight of water which a given weight of coal, burned under a given evaporating vessel, can convert into steam, while undergoing combustion. But this is not the only circumstance requiring investigation, in order to decide their value, even for the purpose of sea-going steamers.

The weight of a given bulk of each coal, in its merchantable condition; the manner in which it burns, whether with much or little flame; the amount and character of its combustible ingredients; its facility or difficulty of ignition; the perfection of the combustion, or the proportion of the whole amount consumed to that of the combustible matter placed upon the grate; the concentration or diffusibility of its heat; the proportion of humidity, and that of the sulphur which it may contain, with the consequent liability, under certain circumstances, to undergo spontaneous combustion—are all points requiring attentive consideration. In addition to these, we have the question of the manner in which each coal behaves when coming to the temperature of ignition; its tendency to retain its original form, the nature and extent of change when any occurs, whether by simply cracking and disintegrating into angular fragments, or by enlarging the bulk, rounding away and obliterating the angles, and yet not agglutinating mass to mass; or, finally, by wholly changing its form and consistence, swelling to a great degree, and cohering so as to form a nearly continuous roof, and thus impeding the passage of air through the ignited coal. In some cases the question of the amount of solid matter which accompanies the gaseous products of combustion in the state of smoke, becoming soot upon the flues of the apparatus in which the combustion is conducted, is one of great practical importance. Of these incidental questions, the amount and character of the incombustible ingredients of different coals is a point eminently deserving of notice. It indicates the deduction which must, in all cases, be made from the heating power of an equal weight of the coal, considered as pure combustible matter; it shows the extent and kind of labor requisite in

managing the furnace; it warns us what to expect in regard to the durability of grate bars, and the adhesion of scoriæ to those important appendages of the furnace. All these subjects must necessarily engage the attention of engineers and furnace managers, and no little portion of the good or bad character in coal may be considered to depend on these circumstances. The relation of the incombustible ingredients of coal to each other is often such as to render the mixture fusible at the temperature of ordinary furnaces, or at least to be, in a certain proportion, reduced to a pasty coherent mass upon the grate, impeding the passage of air, leaving another portion unvitrified, and capable of passing through the interstices between the bars. For different coals this proportion is very different, even when the combustion is conducted as far as practicable in the same manner, and with the same intensity of heat.

In fact, there is scarcely an aspect in which this subject can be viewed, which does not open points of inquiry and comparison of the greatest practical importance, to the naval service. It is not, however, solely with reference to their evaporative power, or their use under steam boilers, that coals are of importance to the navy of the United States, and of all other maritime nations. The very introduction of steam machinery into the navy has largely augmented the amount of workmanship in metals demanded for that branch of service; and the substitution of iron for wood in the vessels themselves, is destined vastly to increase the demand for such varieties of fuel as are best adapted to the various metallurgic arts. It was, therefore, evidently proper, in directing the investigation of the subject of the evaporative power of coals, that the department should require (as it did) the researches to be extended to all their applications. By instituting inquiries intended primarily for its own use and benefit, the Navy Department will have incidentally rendered an equal service to many important branches of art in the country. By inviting, as above stated, the proprietors of mines to furnish their respective coals for trial, it afforded to the mining interest an opportunity of ascertaining the relative value of their own products, as compared with those of many other districts and of foreign countries, and especially of having the peculiar adaptedness of each to its specific object clearly designated.

While so large an amount of both labor and capital is embarked in the mining and transportation of coal, and so many branches of industry depend on it for the successful prosecution of their labors; while so much of domestic comfort and so much of national wealth are, even *now*, in the infancy of our mining operations, made to rely on this material; and while steam navigation upon the ocean, and, eventually, that upon our internal waters, must all be performed by its aid, we are warranted in the assertion that few subjects of a practical nature are more deeply and immediately interesting to the public.

In this view we are sustained by observing how essentially it has contributed to the power and influence of one of the most commercial nations of the world. The coal deposites of a small island, which would itself scarcely cover one of the coal fields of the United States, have afforded the chief means of carrying her conquests to the remotest parts of the globe.

In this view of the value of coal formations, wherever they may exist, it was evidently important to decide, by direct and practical tests, the comparative usefulness of American and foreign coals, as well as the relative value of the former in their numerous varieties.

The point of greatest interest—the heating power of combustible bodies—has, heretofore, been sought to be determined by several different methods. The standard proposed by Lavoisier, and adopted by other chemists, was, the weight of ice melted by the combustion, either in atmospheric air, or in pure oxygen gas, of a given weight of the combustible body. The heat becoming latent during the liquefaction had been previously ascertained. The scale of experiments conducted on this principle was not a *practical* one; small specimens do not always faithfully represent large masses; and, in addition to these objections, a portion of the ice liquefied was liable to be recongealed before leaving the apparatus, so that the weight of water collected was not in every case a true index of the heat imparted. Great discrepancies occurred in the results. By other experimenters, including Count Rumford, the mere rise of temperature in water has been employed as a standard of heating power. But the limited range of temperature to which the experiment is confined requires that either a large quantity of water, or but a small portion of fuel, should be employed. The results would also fail of eliciting some of the important characteristics of coal, which can be fully developed only after a continuous action of some hours, and the use of considerable quantities.

The standard adopted by Mr. Marcus Bull, who some years since gave to the world a valuable series of experiments on the heating power of wood and coal, was the length of time during which a given difference could be maintained between an interior apartment in which combustion was conducted, and an exterior one which was exposed to the cooling effect of the surrounding air, by the consumption of a given weight of each kind of fuel.

The experiments of Mr. Bull were, it is understood, generally limited to a pound or two of each combustible.

The mining engineers of Cornwall, and other parts of Great Britain, have formerly used, as a measure of heating power, the weight of water which could be raised one foot high by the consumption of a given *bulk* of coal, when burned under steam boilers which supplied the pumping engines at their mines. This standard is evidently liable to the objection, that it complicates the question of the heating power of coals, with that of the mechanical structure of engines—the *production* of steam, with its mode of application; questions wholly distinct from each other, and requiring independent solutions.

The distinguished mining engineer, Berthier, of Paris, proposed the employment of the oxide of lead as a material from which to obtain oxygen to effect the combustion of different substances, and made the weight of lead reduced from the state of oxide, by a given weight of each combustible, a standard of its heating power. The composition of the protoxide of lead, or litharge, is well known; and the method of Berthier takes it for granted that the heating power of combustibles is proportionate to the weight of oxygen absorbed. The weight of lead reduced thus becomes indirectly the measure of heat developed.

The German and other European chemists have sought to attain a knowledge of the heating power of fuel by ascertaining the precise chemical composition of the combustible portion, and thence inferring the weight of oxygen which must enter into chemical combination with it during combustion. To supply the oxygen, they have had recourse to compounds which yield it readily and in sufficient abundance—such as the chlorate of potash, the peroxide of copper, and the chromate of lead; but, instead of col-

lecting the potash, copper, or lead reduced, (which would be impracticable,) they collect and weigh the gaseous products of combustion—the water and carbonic acid; and, from the known composition of these, infer the weight of oxygen absorbed, respectively, by the hydrogen and carbon of the fuel. This is, in reality, no other than the method of analysis so successfully applied of late years to discover the composition of organic substances, among which *coal* is undoubtedly to be ranked. The quantity employed in analyses of this kind seldom or never exceeds ten grains. None of the above-described methods appeared to fulfil the conditions required in a practical determination of the evaporative power of the several kinds of coal.

Preference was therefore given to that which had, to a limited extent, been employed by Mr. Fyfe, of Edinburgh; Mr. Schaufhautl, Messrs. Parkes and Manby, in England; and by Dr. Dana, Mr. Hayes, and Mr. Francis, in this country. This method consists in burning the coals under a steam boiler, so arranged and furnished with apparatus as to be capable of complete regulation. The water delivered to the boiler, and the coals supplied to the furnace, are determined both by weight and measure.

The supply of air, the rate of combustion, the pressure and temperature of steam, the proportion and character of the products of combustion, both fixed and volatile, whether left on the grate or passing through the flues, are subject to careful observation and experiment. Here, the standard by which we measure the heating power of different coals is the weight of water which a given weight of each can evaporate from the temperature of 212° Fahrenheit. This standard is probably as constant as any in nature.

With *experiments* conducted on this principle, the *practice* of generating heat for steam navigation, and for many other useful purposes, will be found to correspond in all essential circumstances.

The number of samples of coal on which trials of evaporative power have been made, is forty-one.

Of these, *nine* were anthracites from Pennsylvania, viz:

Two from the Beaver Meadow mines, sent for trial by the Beaver Meadow Railroad and Coal Company; two from the same mines, procured by the department for use in the steamer Union; one from the Lehigh Coal and Navigation Company's mines, sent by that company; one from "Lackawanna," sent by the Delaware and Hudson Canal Company; one from "Peach Mountain," Schuylkill county, sent by the Delaware Coal Company of Philadelphia; one from Forest Improvement mines, Broad Mountain, Schuylkill county; and one from Lyken's Valley Coal Company, Dauphin county.

The mean weight per cubic foot of all these samples, taken in the state in which they came to hand, as determined by actually weighing and measuring the whole of each sample at the time it was burned, was found to be 53.505 pounds. They are all characterized by retaining their form while exposed to the heat of ignition, undergoing no proper intumescence while parting with the small portion of volatile matter which they contain, or only being cracked and disintegrated into angular fragments. Their flame is generally short, of a blue color, and consequently possesses but little illuminating power. The last-mentioned coal, however, (that from Lyken's Valley,) though possessing the principal features of anthracite, also retains more than the usual amount of volatile matter, gives a considerable quantity of luminous flame, burns with more freedom than the gener-

affity of anthracites, and hence constitutes a proper link of transition to the next class, or that of the *free-burning* or semi-bituminous coals.

Of these, *twelve* samples have been tried for evaporative power, viz:

Six from the coal field in the neighborhood of Cumberland, in Maryland, embracing one from Atkinson's mines; one from Neff's mines; two from Easby's mine called "Coal-in-Store;" and one from a quantity of "Cumberland coal," purchased for the use of the navy yard.

Also, six from Pennsylvania, embracing one from Karthaus, on the west branch of the Susquehanna; one from Cambria county, sent by J. Brotherline; one from Lycoming Creek, sent by A. McIntyre, from near Ralston, Lycoming county; one from Blossburg, Tioga county, sent by the Arbon Coal Company, J. W. Johnson, agent; one from Quin's Run, Clinton county, by McDonald & Hallenback; and one from Dauphin and Susquehanna Coal Company, by Isaac Lea, Esq.

Of these coals, the mean weight per cubic foot in their marketable condition is 52.844 pounds. They generally ignite readily, burn with a flame of moderate length, produce considerable intumescence, and, with one or two exceptions, but little agglutination in coking. Their respective peculiar properties will be understood from the tables and explanations hereafter to be reported. The form of masses of these coals is, in some cases, partly preserved in the coke; but a rounding of the edges, and enlargement of bulk, clearly distinguish them from all the anthracites.

The next class of coals is that from the bituminous coal fields in the neighborhood of Richmond and Petersburg, in Virginia; of which *eleven* samples were examined:

Of these, four were from the Midlothian mines, furnished by the Midlothian Coal Company; one from the same mines, procured for use in the navy yard; one from Crouch & Snead's mines, Henrico county; one from the Chesterfield Mining Company, Chesterfield county, (formerly "Blackheath pits;") one from the Creek Coal Company; one from the Deep Run mines of J. Barr, Esq.; one from Tippecanoe mines, near Petersburg, P. D. & F. D. Osborne & Co., agents; and one from the Clover Hill Company, near the same place.

The mean weight per cubic foot, of all these coals, was found to be 49.276 pounds. They burn with a long flame; swell considerably on being ignited; the masses cohere and form a coke, in which the original form of the coal is wholly lost. They correspond in many particulars, as in form, composition, and heating power, with the foreign bituminous coals; of which *six* varieties were tried, viz:

One from Sidney, Nova Scotia, sent by the Cunard Coal Mining Company; one of Pictou coal, sent by the same; also, one sample of Scotch, one of Newcastle, one of Liverpool, and one of Pictou; all procured, by order of the department, from Messrs. Laing & Randolph, extensive dealers in coal at New York.

Of these foreign samples, the weight per cubic foot is, on an average, 49.845 pounds, corresponding very nearly with that of the Virginia coals of the preceding class. As all these coals are found more or less extensively in the markets of our Atlantic cities, it was deemed expedient to give them a full and faithful examination, as well as all the samples sent from the different mines in the United States. Being among the most celebrated varieties of coal known abroad, they often claim the attention of American as well as other purchasers; and being of well-established character, they

will serve as common terms of comparison between the American and such foreign varieties of coal as are not represented in this series.

The coals of the United States above named are, it will be observed, all from the eastern slope of the Allegany mountains. The two following are the only ones from the western coal region, or great Mississippi basin:

One sample from Cannelton, Indiana, about one hundred miles below Louisville, Kentucky—sent by James Boyd, Esq., of Boston; one sample from Hepp & Co., of New Orleans, Louisiana—locality not yet ascertained.

The mean weight of these two samples was found to be 47.23 pounds per cubic foot. They burn with extreme activity, giving a long flame, and yield a light, friable coke.

Besides the above classes, one sample was received from Messrs. Deaton & Barr, of that singular and interesting material known as natural "coke," from a mine of recent exploration in Tuckahoe, Virginia. Its weight per cubic foot was found to be 46.66 pounds. Two mixtures of anthracite and bituminous coal, in certain proportions, and two species of coke, (one from the Midlothian coal of Virginia, and the other from Neff's Cumberland coal,) were also tried.

The mean weight per cubic foot, of these artificial cokes, was found to be 32.57 pounds.

The series of experiments on evaporation was terminated by a single trial of the effect of dry pine wood, of which a quantity had been used daily in heating up the apparatus and preparing it for the reception of coal.

On each sample of coal were made from one to six trials, according to the quantity furnished. The coal consumed in one trial never exceeded 1,567 pounds—this being the greatest quantity which the apparatus could receive in the period allotted to each experiment, including the time requisite for clearing out the residua, making the necessary adjustments, and preparing for a new trial. The total weight of coal consumed in the trials of evaporative power has been nearly 62¼ tons; and the weight used, on an average, 978 pounds per trial. This statement may be sufficient to indicate that the experiments have been made on a scale unobjectionable on the score of magnitude.

The experiments on evaporation were barely commenced in the autumn of 1842; but only so far prosecuted at that time, as to test the working of the apparatus.

They were recommenced on the 5th of April, 1843, and were unremittingly prosecuted, as above stated, until the 18th of the present month. Including the trial of wood, the whole number of experiments occupied 144 days. On each day continuous observations were made during a period averaging from 12 to 14 hours, according to the requisitions of the experiment. In the mean time, trials were made on specimens of all the samples, to test the results of Berthier's plan, as compared with the practical method above described.

The extensive smith shops of this navy yard afforded the means of testing (whenever the amount and nature of the sample allowed) the character of each coal for the working of iron.

As it is, however, generally very difficult, in ordinary smith's work, to establish a standard of effect for this application of coals, the observations must be mainly confined to the behaviour of the coal in burning; the kind of fire it will form, whether hollow or otherwise; the amount and quality

of the cinder it will leave, and its effect upon the iron to which it is applied.

An attempt was made to institute in the chain-cable shop a standard of comparison for heating power between the several coals, by employing a given weight of each in making the links of a chain of given size. A part of these trials have just been completed, and no time has yet been allowed to institute comparisons; but it is believed they will generally confirm the results obtained by evaporation.

The several samples of coal have been, or will yet be, analyzed by the ordinary method of determining the relation of the moisture, sulphur, fixed carbon, gaseous matter, and earthly residua.

A number of the samples have been subjected to trial by the organic method already alluded to.

To give the entire amount of information which the research was intended to elicit, the tables of observations, with the accompanying notes and explanations, aided by the illustrations now in progress, will be found indispensable. As the labor of experimenting is not yet terminated, any attempt to give a precise designation of the rank of each sample might not only fail of its object, but do considerable injustice.

I cannot conclude these remarks without expressing the high satisfaction which I have felt at the zeal, ability, and assiduity with which my principal assistant, Dr. Henry King, has seconded all my endeavors to render these researches worthy of the important subject to which they relate, and worthy alike of the acceptance of your department. To the other assistants and artisans employed in the labors of the experiments, a like tribute is due, for the intelligence and punctuality with which they fulfilled the duties severally assigned to them. To the successive commandants, (Captains B. Kennon and J. H. Aulick,) with the other officers of the yard, and to the principal engineer and machinists, justice also requires that I should express my acknowledgments, for affording the needed facilities for these experiments, and promptly seconding the views of the department, as expressed in the instructions given at the time of their commencement.

I am, sir, very respectfully, your obedient servant,

WALTER R. JOHNSON.

To the Hon. DAVID HENSHAW,
Secretary of the Navy.

REPORT

OF

THE SECRETARY OF THE NAVY,

COMMUNICATING

The result of a series of experiments on coal.

JUNE 8, 1844.
Read, and referred to the Committee on Naval Affairs.

JUNE 11, 1844.
Ordered to be printed, and that one thousand additional copies be furnished for the use of the Senate.

JUNE 17, 1844.
Ten thousand additional copies ordered to be printed.

NAVY DEPARTMENT, *June* 6, 1844.

SIR: An act of Congress, approved September 11, 1841, "making appropriations for the purchase of naval ordnance and ordnance stores, and for other purposes," authorized the Secretary of the Navy to apply a part of the sum thereby appropriated to the purpose of making experiments in matters connected with the naval service and the national defence.

In virtue of this authority, Professor W. R. Johnson, of Philadelphia, was empowered to institute a series of experiments upon coal, on which duty he has been zealously engaged. The result of his labors is herewith communicated in a large manuscript volume, containing the report, accompanied with several sheets of drawings and tabular statements.

The large and growing interests which the United States possess in their vast coal mines, scarcely yet developed, and the numerous national and domestic uses to which the article of coal is applied, will justify the length of time necessarily consumed in making the experiments; and the information contained in this report, it is hoped, will be found to compensate for the outlay.

I have the honor to be, very respectfully, your most obedient servant,

J. Y. MASON.

Hon. W. P. MANGUM,
President of the Senate.

REPORT OF EXPERIMENTS

ON

THE EVAPORATIVE POWER AND OTHER PROPERTIES

OF

COALS.

MADE UNDER AUTHORITY OF THE NAVY DEPARTMENT OF THE UNITED STATES.

BY WALTER R. JOHNSON.

REPORT.

WASHINGTON, *June* 3, 1844.

To the Hon. JOHN Y. MASON,
Secretary of the Navy.

SIR: In a concise preliminary report, which, under date of November 28, 1843, I had the honor to submit to the department, I took occasion to offer some remarks on the necessity which had been found to exist for procuring, by experiment, exact information as to the adaptation of various *coals* to the purposes of steam navigation. I referred to the extensive influence which researches of this nature exercise on the general system of national defences, on the manufacturing, mining, and commercial interests, and on the prosperity and domestic economy of communities having at command the important resources of mineral fuel. I stated the origin and progress of the researches which had been undertaken; pointed out some of the general purposes, primary and incidental, to be effected by the inquiry; referred to the several methods by which experimenters had heretofore sought to determine the heating power of combustible bodies, and indicated the nature of the practical standard of *evaporative power* employed in these experiments. I then gave a classified list of the coals assayed, designating the general properties of each class, and the names of the parties* furnishing each sample. The other methods, both practical and analytical, which were employed, in addition to the evaporative process, to determine the character of each coal, were also briefly enumerated.

Since the time of making that report, a considerable number of the coals have undergone the usual analytical processes; and all the residua of the furnace have been carefully examined, to ascertain the proportion of combustible matter which they contained. In order to present in the most concise form all the information which the experiments were designed to elicit, a tabular view of each has been prepared, faithfully indicating the mode of action of each sample, under the variations of treatment to which it was subjected. From a careful examination of the several tables pertaining to each sample, a series of deductions is obtained; and a separate table embraces, under appropriate heads, the results of each experiment, and the average of the whole for each variety of fuel.

A description indicating the origin, specifying the external characters

* A few inaccuracies occurred in giving the names of persons and companies forwarding the coals, which I would here correct:

1. One sample of Cumberland coal was sent by the New York and Maryland Mining Company, by order of William Young, Esq., president. This was accidentally omitted in the preliminary report.

2. The sample said to be from "Atkinson's mines," should have been from *Atkinson & Templeman's mines.*

3. The samples of Pictou and Sidney were sent by Mr. Cunard, agent for the General Mining Association of London.

4. The small sample sent by Hepp & Co., of New Orleans, was Pittsburg coal.

and internal constitution of each coal, with an account of such experiments as do not refer to evaporative action, has been prefixed to the several tabular statements above referred to. For each *class* of coals, a general synoptical table has been derived from the averages deduced in the manner just described. From these synopses, a still more general table has been prepared, embracing the whole series of coals tried, and indicating the various characters which are most important in a practical point of view.

From this general table are deduced several classifications, according to the *rank which experiment assigns* to each coal. Among the important properties, with reference to which these classifications are made, are the weight under a given volume of each kind of coal; the facility of ignition; the completeness of combustion; the evaporative power for given weights, and that for given bulks; the amount of waste matter from the furnace, and a separate arrangement for the proportion of vitrified cinder. All these properties may be combined in making up an estimate of the relative values of coal for the purposes of steam navigation.

A tabular view of the proportion and characters of the residua left, after burning the several coals, is annexed. A number of other tables, relative to distinct classes of observations, will be found described in their proper places. Among these, one relates to the velocity with which the gases, produced by combustion, traversed the flues and chimney; others mark the influence of admitting currents of air to mix with the combustible gases at the furnace bridge, and distinguish separately the economy in time from that of fuel, due to such an arrangement. But, perhaps, none of the tables will be found more instructive than that which relates to the composition and heat-absorbing power of the gases, drawn from the flues during the combustion of numerous varieties of coal.

This table serves to show how large a proportion of atmospheric air always passes unchanged through our ordinary furnaces; and more particularly does it show the variableness of that proportion under different circumstances of the combustion; and, what is of not less practical importance, it enables us to ascertain what proportion of the heat, actually developed by the combustion of fuel, is applicable to useful purposes in the generation of steam, and how much is inevitably wasted in getting rid of the products of combustion. It serves the further purpose of determining the relation between the constitution of coals and their effective heating power; a question of the greatest importance to all who are concerned either in the selection or the use of fuel.

The general arrangement which I have adopted in presenting the materials of this report, is, after a few remarks on the prevalent measures of coal, to explain the several kinds of apparatus used, either in the analyses or the evaporative tests of coal. The latter will be found to embrace a description of the furnace, with illustrative plans, sections, and elevations; the construction and setting of the boiler; the apparatus for supplying it with water; that for drying the coals; the steam gauge, with its application; the gauge to show the draught of the chimney; and the apparatus for testing the products of combustion.

Following the description of apparatus for ultimate analyses of coals, will be found some experiments to test the relative value of re-agents generally employed in such analyses.

The order of arrangement in describing the coals follows nearly that of their freedom from volatile matter, and is substantially the same as was

laid down in my preliminary report. The anthracite class is made to embrace the samples of fuel of analogous properties—such as "natural coke," artificial coke, and mixtures composed of four parts of anthracite and one part of bituminous coal.

1. *Measures of coal.*

The coal bushel in England was formerly "a metallic cylinder 19½ inches in diameter inside, and 7½ inches deep. In filling it, the coals were to be heaped six inches high in the middle, so that a line drawn from the apex to opposite sides of the bushel would be 11½ inches in each direction."* This would give the contents of a bushel of coals equal to 2,725.4 cubic inches; while the bushel, imperial measure, of the same country, is 2,218.192 cubic inches; and one bushel, Winchester measure, is 2,150.42 cubic inches.

The chaldron of coals with "ingrain" measure 104,809.572 cubic inches; and without "ingrain" 99,809.64 cubic inches. The former would be 38.45 bushels, as measured in and on the cylinder above described, and the latter 32.95 such bushels. Eight chaldrons of coal in Newcastle, are equal to 15½ chaldrons in London. The chaldron in Newcastle weighs 53 cwt.; and, consequently, in London it weighs 27.35 cwt. The same authority which furnishes these data,† also apprizes us that 88 pounds of coal make a bushel.

From the data furnished in the course of the following research, it will be evident that wide diversities exist in the weights of given bulks of different kinds of coal, and consequently great uncertainty must arise from attempting to estimate, by bulk alone, the value of any species of this material. It was not, therefore, deemed expedient to introduce anything in relation to the *bushel* of coals, either in regard to weight or efficiency; but to reduce all measures to the standard of a *cubic foot*, in which measure the contents of the bunkers of a steam ship are readily ascertained.

2. *General plan and arrangement of apparatus for testing the evaporative power of coals.*

The apparatus employed for this purpose is represented in plate II, figures 1, 2, and 3; the first being a side, the second a front, and the third a rear elevation.

In these, as well as in the several longitudinal and transverse sections, the same references are, as far as practicable, applied to the same objects. the lateral elevation (fig. 1) brings into view not only the brick work of the stack, containing, as seen by a dotted outline, the boiler B, the water tank W, the intermediate cistern or filling apparatus C, the two safety valves V and V', the drying apparatus K, the water gauge G, but also the small adjacent apartment, in which are placed the manometer or steam gauge M, connected with the boiler by the iron tube *l;* the barometer *b*, with its attached thermometer *i;* as also the gas drawing and analyzing apparatus placed in the same apartment, including the chloride of

* See Treatise on Fossil Fuel, Collieries, and the Coal Trade: London, 1841—page 378.
† Grier's Mechanic's Pocket Dictionary, page 335.

calcium tube n, the sulphuric acid and asbestos tube o, the potash tube p, the second chloride tube q, the receiving jar r, with the arrangement for counterpoising it in the mercurial bath, and the graduated jars s, s, each furnished with a stopcock, by means of which it can be brought into communication with the receiver r, in order to receive portions of the gas drawn from the chimney to be tested for oxygen and other materials. This view also exhibits the two gauge cocks c, c, the dampers d and d', of which the former is represented as open, and the latter closed. It also exhibits the connexion between the safety valve V, and the chimney into which the steam was discharged through a 3-inch tube E; and the thermometer, f, showing the temperature of steam in the boiler.

It shows, at a, the opening of the iron tube in which is inserted the thermometer for measuring the temperature of the air on arriving at the grate. The rear end of the boiler (fig. 3) is seen to be furnished with a large stopcock, H, for discharging its contents; and the steam drying apparatus has a tube, m, projecting through a partition, and discharging into the open air the steam which has traversed that apparatus.

Three sets of steps are seen, of which the first leads from the pavement to the platform or flooring laid over the brick work covering the boiler; the second leads from the level of that platform up to the water cistern, W, enabling the observer to read the scale on the rod, v, and to note the temperature of the water by a thermometer kept suspended in the cistern; and the third, placed in the office where the manometer and barometer are situated, enabled the observer to read those instruments, which are necessarily at an elevation of 7 or 8 feet from the pavement; x, x, are small puppet valves, by means of which either steam or water is allowed to escape from the water gauge G.

The height of the chimney to the top of the brick work is 41 feet, and its interior is 18 inches square; or its cross section is 324 square inches. The sheet-iron addition is 22 feet and ¾ of an inch in height, 22.9 inches in diameter, and its cross section 412.5 square inches.

In fig. 2, plate II, is seen a front elevation of the apparatus, omitting the manometer and the apparatus for the analysis of gases. The dotted circle B represents the outline and defines the position of the boiler. The two cast-iron plates k, k, close the apertures in the brick work, through which the interior flues are reached in order to be swept: w is a similar cover to the side flue at the left of the boiler; and w', a plate closing a sweep-hole leading into the chimney.

g, g', and h, show the situation of the winches by which the several stopcocks (having on fig. 1 the same references) are managed; l, shows a section of the tube leading to the manometer; O, is the air port through which the air to supply the furnace entered beneath the ash pit, to find its way to the vertical air chambers on the sides of the stack, thence beneath the back end of the main fire flue to the grate. Just within this port are seen the two small thermometers e, and e', the latter having its bulb extending below the scale, and covered with a moistened cloth. These two constitute the dew-point apparatus. At j, and j', are two openings for the insertion of thermometers, one into the lower, and the other into the upper flue, by which the gases found their way into the chimney.

d is the damper, with its enclosing cast-iron frame, by which the pas-

sage to the chimney from the two interior flues *k*, *k*, is cut off. The damper *d'* being drawn, opens a passage to the side flues opposite to *w*.

Between the two plates *k*, *k*, is seen a section *i* of the tube through which the gases were drawn after having passed the two interior return flues; *y*, *y*, are the fire doors, and *z*, *z*, the ash-pit doors—all closed as when the furnace is in action. L is the small subsidiary furnace used to augment the draught of the chimney, its ash pit opening being shown in front at the bottom, and its damper partly raised at N. The water gauge G, is seen to be furnished with a scale which was divided into inches and parts, above and below its zero, or *normal level*. At its upper and lower extremities are likewise seen screw nuts *n*, *n*, by which a complete opening through the glass tube is obtained, allowing it to be readily cleaned and wiped out. The remaining letters on this figure have reference to objects corresponding with those on fig. 1. In both figures the safety valves are seen to be surmounted by spindles or rods of about 30 inches in height, traversing guides, and supporting circular leaden weights, each weight having a slot by which it can be placed on its support.

Fig. 3 is a rear view of the apparatus, showing the outline of the end of the boiler by the dotted circle B. The openings of the interior flues *k*, *k*, and the exterior ones *w*, *w''*, as well as that of the fire flue *y'*, are also severally indicated by these letters. The drying apparatus K, and the discharging cock H, the steam pipe *m*, from the drying apparatus, are referred to in the above description of fig. 1.

Fig. 4, plate II, is a vertical cross section through the water tank W, the filling apparatus C, the boiler B, and the several air passages and flues. The two side chambers, by which the air finds its way from the front to the rear of the furnace, are indicated by *s*, *s*; its return to the front at the level of the ash pit is marked by *z*; the level at which the thermometer is placed to show the temperature of the air on arriving at the grate is marked by *a*, though the tube containing it would not be actually cut by the vertical section now referred to.

The thermometer, marking the temperature of the water in the cistern W, is shown at *t*; *w* and *w''* are the exterior or side flues, and *k*, *k*, the interior return flues. One of the supporting pillars of brick (of which five were placed under the length of the boiler) is seen in the middle of the flue *y*, *y*, which is the main fire flue beneath the boiler.

The two dotted lines, *o*, *o*, and *n*, *n*, mark the levels at which the horizontal sections, figs. 2 and 3, plate III, are respectively taken.

Plate III, fig. 1, represents a vertical longitudinal section through the axis of the boiler, and such of its appendages as lie in that vertical plane. The water tank, with its float, the filling apparatus, safety valves, water gauge, drying apparatus, thermometer in the steam, and pipes for the discharge of steam, are all indicated by the same letters which have been employed in describing them in preceding figures.

In addition, this section brings into view the air passage at the level of the ash pit *z*, towards which the current of warm air is represented by the arrows to be flowing from rear to front.

It also shows the position of the grate G, and the air plate *p*, through which a part of the current of air is represented to be passing. It likewise shows the subsequent passage of the products of combustion beneath the boiler along the main fire flue *y*, in which the pillars of brick already mentioned are seen at *q*, *q*, *q*, *q*, *q*. The entrance of the gases into one of

the interior flues, *k*, is marked by one of the curved arrows; and its exit, on its way to the upper or *side* flue, by another. The position of this upper flue, where it crosses the rear end of the boiler, is seen at *w*.

At *i* is seen the manner in which the small iron tube (*i*) is inserted into the space opposite to the openings of the interior flues. This part of the apparatus is seen enlarged at *i'*, where the enlargement at *o* is filled with asbestos. At the opposite end, the chloride of calcium tube, *r*, is united with *i* by the usual elastic juncture. At *a* is a cross section of the thermometer (*a*) and its containing tube. This section shows the main supports of the boiler to be the fire-door frame at the front, and a cross bar of cast iron (*u*) near the rear of the furnace.

Fig. 2, plate III, is a horizontal section taken a little above the level of the grate at the height indicated by the line *o, o*, fig. 4, plate II, exhibiting the perforated air plate at the furnace bridge, with the closing plate *p*, the air passages *s, s*, with the indications of currents of air. The position of the wet and dry bulb thermometers in the opening O, beneath the hearth plate in front of the grate G, is indicated by the dotted figures *e, e'*. The progress of the air entering below the hearth at O, and soon after turning to the right and left through passages, indicated by the arrows *g, g, g, g*, into the chambers *s, s*, and thence passing in a united current first to the front beneath the floor of the fire flue, and then through the grate and above that floor, as denoted by the arrows *g', g', g'*, is presented to view in this section. The dotted figure of the thermometer *a* is made to represent its position beneath the bottom of the flue *y*.

The interior of the chimney stack is seen at S, and the several brick supports of the boiler at *q, q, q, q, q*.

Fig. 3, plate III, is a horizontal section taken at the level of *n, n*, fig. 4, plate II. Besides the boiler B, and its interior flues *k, k*, this section shows the upper portion of the air chambers *s, s*; the thermometer *j'*, which marked the temperature of the gases escaping to the chimney; the openings *w, w, w', w''*, by which the upper flues and the chimney were reached, and the complete circuit of the air in five different directions. This last purpose is accomplished by means of the different degrees of strength given to the lines of the arrows, and by the number of accents applied to the letters attached to them. Thus, the faintly dotted arrow *g* indicates the current as flowing beneath the fire flue to reach the grate; *g', g'*, the same air returning along the main fire flue to the back end of the boiler; *g'', g''*, the divided current traversing the two interior flues; *g'''*, the current as it passes from the two interior flues into the upper and exterior flues, which it is seen to traverse to its point of exit into the chimney S.

3. *Of the boiler and its appurtenances.*

The boiler employed in these experiments is cylindrical in form, 30 feet in length, 3½ feet in diameter, and having near its lower arch two interior return flues, each of 10 inches interior diameter. The heads are flat, of wrought iron, and are securely stayed to the upper shell by oblique bolts. The boiler is furnished with two safety valves loaded directly; that is, without the intervention of a lever. Each valve has a lower base about three inches in diameter, and, consequently, an area of about 7 square inches.* Of these two valves, that represented at V, fig. 1, plate

* The true value of the lower base of V was 6.975, and that of V' 7.163 square inches. The upper base of the former was 9.73; that of the latter, 9.62 square inches.

II, near the front end, is connected with a tube E, for the escape of steam leading into the chimney, where its orifice is turned upwards.

The other valve, V', is connected with an escape tube leading to the copper drying apparatus K, (fig. 1, plate III,) and thence passing horizontally through the side of the building into the open air.

At M, (fig. 1, plate III,) is seen the man hole, affording admittance to the interior of the boiler.

At Y is an iron tube, closed at bottom and open at top, to contain oil, and in which is placed the thermometer *f*, by which the temperature of the steam is ascertained.

At *l* is a wrought-iron pipe leading from the steam chamber to the manometer. A stopcock cuts off, when required, the communication between the boiler and the manometer.

At the furnace end of the boiler is the glass water gauge G, furnished with stopcocks to cut off, when necessary, its communication with the boiler.

The centre of the water gauge is 6 inches below the upper interior arch of the boiler.

Near the water gauge are placed two gauge cocks, *c*, *c*, (fig. 2, plate II,) one above and the other below the level just referred to.

At its front end, the boiler rests on the cast-iron frame containing the fire and ash pit doors; and at the opposite end, on a strong cast-iron bar supported at its two ends in the side walls of the furnace. Besides these two principal supports, it has five supports of brick, 4 feet apart, resting on the cast-iron floor of the flue below, each of the size of a single brick laid flatwise on its side, and lengthwise in the longitudinal direction of the boiler. These supports, and other arrangements in regard to the setting of the boiler, will be understood by reference to the vertical longitudinal section, fig. 1; the plan fig. 2, plate III; and to the vertical cross section, fig. 4, plate II; in all of which they are designated by *q*.

The arrangement of the several flues, and the directions pursued by the products of combustion, from the time of leaving the grate till they arrive at the base of the stack, will be also perceived on examining the same figures, together with the plan fig. 3, plate III, taken at the level of the upper or external flues, by which the air eventually reached the stack.

It will be observed on the transverse vertical section, that the walls enclosing the furnace and boiler are double, containing between them air chambers, *s*, *s*, running the whole length of the boiler, and serving to convey the air from the front to the rear of the structure. Having passed along these two chambers in a divided current, and become warmed by the heat passing through the inner walls, which are 13 inches thick, it turned downward to the level of the ash pit, and came in a single current through the passage Z, (fig. 4, plate II,) immediately beneath the main furnace flue *y*, until it arrived at the rear of the grate. Here it entered the fire, passing either wholly through the fuel on the bars, or, in part, through the "air plate" *p*, (figs. 1 and 2, plate III.)

Having passed the grate, the air, with the products of combustion, first passes horizontally beneath the lower arch of the boiler to the rear, thence returns in a divided current through the two interior return flues, *k*, *k*, (fig. 4, plate II,) to the front; after which, it either passes through the opening of the "*lower damper*," *d*, (plate II, fig. 2,) into the chimney. or, when that is closed, and the "*upper damper*," *d'*, is opened, it ascends

from the ends of the two return flues into the left-hand exterior flue *w*; passes along it, in a united current, once more to the rear of the boiler; crosses the end, still at the same level, and enters the right-hand exterior flue, which it traverses till it reaches the exit flue, by which it finally arrives at the chimney, *s*; entering the latter at a level only 14 inches higher than when it passed by the other exit flue through the lower damper.

From this description, it will be observed that the air which supplies the combustion passes first into a chamber beneath the ash pit, about 7 feet long, and 3 feet 3 inches wide, along the sides of which are several openings, by which it finds its way into the two longitudinal side chambers, 30 feet long, 6 feet high, and 9 inches wide, between the two side walls; and having arrived, by these, at the rear of the boiler, passes 25 feet beneath the flue, arriving at the *centre* of the grate after a course of 60.5 feet. Thence a course of 58.5 feet brings the products of combustion to the aperture through the passage, by the lower damper, into the chimney; and of 62.5 feet farther, or 121 feet from the centre of the grate, to the point where they finally quit the boiler by the exterior flue. The part of the lower arch of the boiler, exposed to the action of heat, is 130 square feet, and that of the two return flues is 157 square feet; so that when the combustion was conducted by allowing the products to make their exit through the lower passage, or after passing twice the length of the boiler, the heated surface was 287 square feet. The boiler surface exposed in the exterior flue, or second circuit, is 90.5 feet; making the entire surface, when the products traversed four times the length of the boiler, 377.5 square feet. The grate being 5 feet long, and 3 feet 3 inches wide, when at its full dimensions, its area was 16.25 square feet; and the ratio of the grate surface to the heated surface, when the combustion was carried on through the lower damper, was 1 : 17.66; when through the upper damper, making the circuit 121 feet long, this ratio was 1 : 23.23.

When the air-plate bridge was introduced, it covered 8 inches of the length of the grate, reducing its area to 14.07 square feet, and increasing the ratio of heated to grate surface to $\frac{377.5}{14.07} = 26.83$ to 1.

During a few trials the grate was still farther reduced in area by the introduction, at the front end next to the fire doors, of a plate of iron 3 feet 3 inches long, 11¼ inches wide, and one-fourth of an inch thick. This is termed the "*coking plate*," and was used while burning some of the samples of bituminous coal, which were so fine that large portions were liable to pass through the grate. With this plate in place, and the air plate in its usual position, the size of the grate was reduced to 11.375 square feet, and the heated to the grate surface increased to $\frac{377.5}{11.375} = 33.18$ to 1.

On one occasion, instead of contracting the area of the grate by means of the coking plate, it was diminished by placing a row of bricks flatwise along each side of the furnace, reducing the grate surface to 10.291 square feet, and the ratio of *heated* to *grate* surface to $\frac{377.5}{10.291} = 36.68$ to 1.

The grate was, in general, about 9 inches at the front, and 10 inches at the back end, below the lower arch of the boiler. On one or two occasions, however, which are noted in the tables of experiments, it was varied a little from this distance; but as no advantage appeared to attend the change, it was restored to this, as the most convenient working distance for all the varieties of fuel employed.

The grate bars used were three-fourths of an inch thick, and the spaces between them half an inch wide. They were supported at the centre, as

well as at each end, by a cast-iron bar 2½ inches thick, and 4 inches deep. Hence, when the grate was at its full size, the total amount of air passages through the grate was nearly 5⅝ square feet.

The interior capacity of the boiler was such as to contain, when filled to the centre of the gauge tube, or *normal* level of the experiments, with water of 66° temperature, 12,795 lbs. This is the result of an experiment made after clearing out and wiping dry the interior of the boiler, and re-filling it through the measuring cistern. Of this quantity, 493 pounds were then withdrawn, leaving 12,302 pounds, filling the boiler to within 1.1 inch of the normal level. On subsequently heating this to 230°, the water in the gauge, after taking all due precaution to withdraw the cold water from the glass tube, and filling it with that which was hot, stood once more at the normal level. Hence the apparent expansion of water in iron by an addition of 164 degrees of heat, is equivalent to $\frac{493}{12302}=0.0407$, or a little more than one twenty-fifth part of its bulk at 66.°*

4. *Supply of water.*

The supply of water to the boiler was effected by means of the apparatus and hand gears seen at *c*, fig. 1, plate ii. From the tank or cistern W, the upper stopcock *g* allowed the water to descend into the intermediate small iron cistern C. When this cistern was full, the opening of the cock *h* allowed the steam from the boiler to act on the upper surface of the water in C; the first cock *g* being then, of course, closed. The opening of a third cock *g'*, at the bottom of the cistern C, now permitted the water to descend into the boiler, while its place became occupied by steam. On closing the cocks *g'* and *h*, and once more opening the upper cock *g*, water instantly followed, condensing the steam and occupying its place. The apparatus was then in a condition to repeat the supply whenever the exigencies of the boiler demanded. Whenever a *set of observations* was made, it was with the intermediate cistern C full.

The large tank W (which was 5 feet and ½ inch on one side of its base, 4 feet 11½ inches on the other, and 3½ feet deep) contained, when filled to its usual height, about 5,110 lbs. of water. A float board rested on the surface of the water, and carried a light wooden rod *v*, passing through two guides, (as seen in plate ii, fig. 1.) On this rod were marked the weights of water contained in the cistern at different heights. The graduation of this scale was effected by actually weighing into the cistern successive portions of 100 lbs. of water, and marking the point indicated on the rod

* The observations made on the gradual rise of temperature, and the corresponding weights of water which it had taken to fill the boiler, as much as the expansion by heat now did, gave the following table:

From 66° to 114¼°,	viz:	48°.5,	the increase was equivalent to	the bulk of	69 lbs. at 58°,	or 1.42 lbs. to 1°
114¼ to 149	"	34°.5,	"	"	81 "	or 2.35 " to 1
149 to 180	"	31	"	"	97 "	or 3.13 " to 1
180 to 207	"	27	"	"	86 "	or 3.18 " to 1
207 to 223	"	16	"	"	89 "	or 5.56 " to 1
223 to 230	"	7	"	"	71 "	or 10.14 " to 1

This great increase in the rate of expansion of water above the boiling point, being nearly 7¼ times as great in the range of the last 7 degrees as in the first stage of 40°, may probably possess some interest beyond that which attaches to it as a means of correcting the results of certain observations taken during this research. The subject has not, to my knowledge, attracted much attention among experimenters. It will be remarked, that this rapid augmentation of the rate of dilatation of water in iron, is not prevented by the conversion, at the same time, of a considerable quantity of water into steam of a high density.

by a fixed brass band attached to one of the guides. This weighing took place when the water was at a temperature of 58°. A careful re-examination of the same gauge, when the water weighed was at 66°, showed that within these limits no appreciable difference of measurement, due to difference of temperature in the water, could be found while filling in 2,500 lbs. of water. The expansion of the materials of the cistern in this part of the scale was, therefore, inferred to be equivalent to that of the water which it contained.

By the experiments of Count Rumford, the expansion of water between the freezing point and the highest temperature at which water was delivered to the boiler in any of these trials, (say about 88°,) is only 7.65 parts in 2,000, or 0.38 of one per cent. The lowest temperature of water in the tank, which will be found recorded in any of the tables, is 40°; near which point it is known water is at its maximum density; and from which point to 60°, the expansion is also known to be no more than 0.00008 of the whole volume at the former temperature. Hence, for all temperatures below that at which the water was weighed into the cistern, and the float rod gauged, any error from the difference of temperature in water is absolutely insignificant. In order to bring the upper part of the scale to an experimental test, I partly filled the cistern with water at 40° temperature, until the gauge rod marked 3,700 lbs. To these were added successive carefully weighed portions of 50 lbs. each of water, at a mean temperature of 190°. After each addition, the temperature was ascertained; the water being first thoroughly mixed, to obtain a uniform temperature throughout.

After the tenth addition, the temperature was exactly 58°, and the gauge marked accurately 4,200 lbs.

After the twentieth addition, the temperature stood at 72°, and the gauge marked 4,713 lbs., showing the expansion to be $\frac{276}{100000}$ of the whole, or 0.276 of one per cent.

After the thirtieth addition, the gauge marked 5,221 lbs., and the temperature had risen to 82°.25. Hence the dilatation had been very nearly 0.4 of one per cent.

From the series of experiments just referred to, a scale of co-efficients for correction was constructed, by which the apparent weight read upon the gauge rod is reduced to the real weight of water which passed into the boiler. But, as already seen, no correction of this kind is really needed, except when the temperature exceeded 66°.

The following table shows the average temperature of water in the cistern, with the proportion which the actual weight of water, in each case, bore to the apparent weight delivered to the boiler. After the computation of water to 1 of coal from initial temperature had been made, this correction was applied, and furnished the line numbered 40 in the tables of deductions, and styled "*water to 1 of coal, corrected for temperature of water in cistern.*"

Table of co-efficients for correcting the weight of water delivered to the boiler at different temperatures.

Temperature.	Ratio of actual to apparent weight of water.
58°	1.0000
65	0.9985
70	0.9977
75	0.9969
80	0.9963
85	0.9957
90	0.9953

Small as is the correction required by the cause now under consideration, it has not been deemed expedient to omit the estimation of its efficiency in modifying the results.

5. *Drying apparatus connected with the steam boiler.*

This apparatus had for its object the determination of the hygrometric character of the several coals; and from this the loss which each sustains in combustible matter and in useful effect, from evaporating water out of its own mass, instead of the steam boiler. It will readily be perceived that the weight of water in any species of fuel is far different in its influence from an equal weight of incombustible earthy residuum; for the latter merely detracts so much from the weight of the raw material, while the former is not only useless in regard to the production of heat, but absolutely absorbs both the latent and sensible heat of steam, and carries into the chimney not only as much heat as would accompany the same weight of vapor from the boiler, but also the sensible heat in excess above that of the steam, as indicated by the thermometer which marked the temperature of the escaping gases.*

6. *Of the manometer, or mercurial steam gauge.*

This apparatus is seen at M, fig. 1, plate II.

A cast-iron cup of a cylindrical form, half an inch thick, about 2 inches interior diameter, has a lid of the same material and thickness, accurately fitted by grinding to the upper rim, and kept in place by a pair of wrought-iron stirrups passing under the bottom of the cup, and retained in close contact with the lid by set-screws beneath the bottom. Through a hole

* If the ratio of the moisture to the total weight of coal be r, and the ratio of the ashes be a, then will the really combustible matter be represented by $1-a-r$. And if l be the latent heat of vapor at 212°, t the temperature at which the fuel is supplied to the grate, and t' that at which the products of combustion leave the boiler, then $l+(t'-t)$ will be the whole *number of degrees of heat* absorbed by the moisture of the fuel, and $r(l+(t'-t))$ will be the *quantity of heat* applied to it, and which is, of course, so much detracted from the useful effect applicable to the boiler. In the tables of deductions are given the amounts of water *to* 1 *of combustible*, from 212°. The weight of water to 1 of fuel, after deducting the ashes, is there calculated on the supposition that the water receives only latent heat. If w be the tabular weight of water to 1 of combustible, then lw = to the amount of heat supplied by one part of coal, including its moisture, but excluding the ashes. Hence the whole quantity of heat developed and applied to the production of vapor, by one part of the fuel, in burning, is $lw(1-a)+r(l+(t'-t))$; and $\frac{lw(1-a)+lr+(t'-t)}{1-a-r}$ gives the quantity of heat from 1 of true *combustible*.

in the centre of the lid, passes a glass tube open at bottom, but hermetically sealed at top. It is firmly cemented into the lid, and descends nearly to the bottom of the cup, through the mercury therein contained. The cup is connected with the top of the boiler, near its front end, by the wrought-iron tube *l*, about 15 feet long. This tube traverses a board partition, constituting one side of a small separate apartment or office, which consequently insulates the manometer and other apparatus from all direct radiation from the furnace.

The cup rests on a wooden transverse support crossing the apartment. Attached to this is a frame supporting the scale, of boxwood, on which the graduations of the instrument are placed. On one side of the tube are marked on the scale the heights above the original level of mercury in the cup, expressed not in inches, but in *parts of an atmosphere* of 30 inches in height. On the other side is placed a set of divisions, commencing from the top of the tube, and representing equal portions of its interior capacity, or *volumes* of the air which it contains.

A thin sliding band of brass embraces the scale, and carries on its front a ring which encircles the tube, and, having its upper edge on a level with that of the band, serves to guide the eye in noting the level of mercury in the tube, and marking its correspondence with the two graduations just referred to.

The total length of the tube is 32.25 inches. Its interior capacity was divided by filling it with successive equal weighed portions of mercury, and marking on the glass the volumes thus indicated.

The whole tube contained 10.9116 volumes; and when first inserted in its place, it was filled with air thoroughly dried at a temperature of 39°, and when the barometer was at 30.03 inches.

As the temperature rose with the advance of the season, the expansion caused, in the intervals of experiments, three successive discharges of air, notwithstanding the column of mercury in the cup, which was 1.127 inch above the lower extremity. The first escape took place after the first day's experimenting, and reduced the remaining bulk of air to 10.2433 volumes when under a pressure of 30 inches of mercury at 32°.

The second escape took place after 35 days, (that is, on the 27th of May,) and reduced the remaining volumes to 9.3038 at the same pressure and temperature.

The third escape took place on the 16th of June, in consequence of a partial vacuum formed in the boiler, by admitting a large quantity of cold water, after having blown out its contents for the purpose of cleansing. This discharge reduced the remaining volumes to 4.1624 at the temperature of 32° and pressure of 30 inches. It placed the manometer beyond all danger of farther loss, and the bulk of air remained without variation to the end of the series of experiments.

Near the manometer, and at the same level, was suspended a barometer of the ordinary construction.

The two instruments were about 12 feet above mean tide water. The barometer had a thermometer attached, which was regarded as indicating the temperature of the mercury and air of the manometer, as well as of the barometer itself.

As the iron conducting tube *l* was carried almost exactly on a level, or with a slight inclination only towards the manometer, from the curved

portion near the boiler, it contained no appreciable *head of water* which could sensibly affect the pressure in the latter.

The water within it remained cold, except for a short distance—say 2 or 3 feet of the portion near the boiler.

The manometer served not only to mark the *variations* of pressure of steam from one observation to another, but also to calculate the absolute pressures* in atmospheres, as well as in pounds per square inch.

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* To effect this calculation, let p be the observed height of the barometer in parts of an atmosphere of 30 inches of mercury, and let p' be the equivalent weight or *height of column* of mercury, at 32°.

Since mercury expands $\frac{1}{9990}$th part of its volume by 1° Fahrenheit, therefore will $p'=p\left(\frac{9990}{9990+(t-32)}\right)$; t being the temperature marked by the attached thermometer at the time of observation.

The mercury descended in the cup of the manometer one-hundredth part as much as it ascended in the tube. Hence if h be the height (in parts of an atmosphere) observed in that instrument, $h+.01h$ will be the height above the existing level in the cup, and $(h+.01h)\times\left(\frac{9990}{9990+(t-32)}\right)$ will be the height of the same column reduced to a temperature of 32°. This may be represented by h'.

When no steam was in the boiler, and its interior was open to the air, it is evident that the compressing force exerted on the air contained in the manometer was equivalent to the difference between p' and h'; or, in terms of the observed data, it is $=p\left(\frac{9990}{9990+(t-32)}\right)-\left((h+.01h)\times\left(\frac{9990}{9990+(t-32)}\right)\right)$. This quantity, which represents the elastic force of the air within the manometer when unaffected by the pressure of steam, enables us to reduce the observed volumes of air to the bulk which they would possess under the pressure of an atmosphere of 30 inches of mercury at 32°.

1. Let the observed volume be called V. Then, as at the temperature t it will be greater than at 32°, its bulk at the latter temperature may be represented by V'. From the generally received expansion of air by heat, $V'=V\left(\frac{480}{480+(t-32)}\right)$.

2. Having obtained the *bulk* and elasticity of the enclosed air at 32°, under its actual tension, we obtain, by the well-known law of Mariotte, its volume when reduced to the tension of one atmosphere at the same temperature. Thus, $1 : p'-h' :: V' : V'(p'-h')$.

The volume thus calculated for *unity of pressure* and a standard temperature, may be compared with the volume observed in the same mass of air when subjected to the pressure of steam; but it must first be corrected for temperature at the time of such observation. Thus, let t be the temperature of the attached thermometer, observed when the manometer is subjected to a pressure of steam; let H be the height of the column of mercury simultaneously observed, and v the volume of contained air at the same time; then the equivalent of H, corrected for depression of mercury in the cup, and reduced to a temperature of 32°, may be represented by H'. And by the same principle as above adopted, $H'=(H+.01H)\times\left(\frac{9990}{9990+(t-32)}\right)$.

By the law already cited, $v'=v\left(\frac{480}{480+(t-32)}\right)$, where v' is the volume which the compressed air would have, if brought to 32°. The elasticities being inversely as the volumes, we have $v' : V' :: p'-h' \cdot V'\times\frac{p'-h'}{v'}$.

Adding to the last result the corrected height of the mercurial column H', we obtain $V'\times\frac{p'-h'}{v'}+H'$ for the pressure of steam in atmospheres above a vacuum. Deducting unity, and multiplying by 14.768, (the weight in pounds avoirdupois of a column of mercury having a base of one square inch and a height of 30 inches at 32°,) we have the pressure of steam *in pounds avoirdupois above one atmosphere*. Calling this pressure F, the formula takes the form—

$$F=14.768\times\left(\left(V'\times\frac{p'-h'}{v'}\right)+H'-1\right).$$

The following example may illustrate the application of the above formula, both to the finding

It has not been deemed necessary to calculate every observation separately, but only to give the mean pressure during the period of each day in which it was ascertained to have been nearly uniform.

The extreme sensibility and perfect security of the manometer as a measure of the pressure of steam in a high-pressure steam boiler, as proved by my own experiments both before and since the commencement of researches on coal, and as well under more than 200 pounds to the

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of the volume of the included air reduced to the standard temperature and pressure, and to the determination of the mean pressure of steam, in atmospheres and in pounds:

On the 28th of June, during an experiment on Beaver Meadow anthracite, the height of the mercurial column in the manometer, before raising steam, was .348 atmosphere, the corresponding volumes of air 7.08. The barometer stood exactly at 30 inches, and the attached thermometer at 79°; or, $p = 1.0000$, $t-32 = 47°$: consequently, $p' = \frac{9990}{9990+47} \times 1 = .99534 =$ the barometric pressure reduced to 32°. $h = .348$, and $.01h = .00348$; so that $h' = (h + .01h) \times \left(\frac{9990}{9990+t-32}\right) = .35148 \times \frac{9990}{10037} = .34984, =$ the corrected height of mercury in manometer. Hence $p'-h' = .99534 - .34984 = .64550 =$ the elasticity of the included air.

V is by observation 7.08. Hence $V' = 7.08 \times \frac{480}{527} = 6.4485 =$ the bulk under the same tension if reduced to 32°. From these data, $1 : 0.6455 :: 6.4485 : 4.1627 =$ the volume of included air reduced to 32° and 30 inches, or *unity of pressure*.

During the progress of the experiment, the period of steady pressure lasted from 10 a. m. to 5.30 p. m., in which were made fifteen sets of observations. These give, for the mean temperature of the attached thermometer, $81° = T$; for the mean height, $H = .5358$; and for the mean volume of air, $v = 5.213$: consequently, $T-32 = 49$, $H + .01H = .54116$, and $H' = .54116 \times \frac{9990}{10039} = .53853 =$ the corrected height of mercury in manometer for this period. $v' = 5.213 \times \frac{480}{529} = 4.7301 =$ the volumes under the same pressure, had the temperature been 32°.

Again: as $V'(p'-h') = 4.1627$, $\frac{V'(p'-h')}{v'} = 4.1627 \div 4.7301, = .88002$; to which adding $H' = .53853$, we obtain for the total pressure of steam above a vacuum, 1.41855 atmospheres. Deducting unity and multiplying by 14.768, we get 6.1812 pounds as the mean pressure above an atmosphere during that day's operations.

It is to be observed that an opportunity was not every day afforded for verifying the true volume of air in the manometer. The boiler often contained, in the morning, steam of considerable tension from the preceding day's operations. By means, however, of verifications made on seventeen different days, after the 16th of June, it was ascertained that the calculations afforded a mean of 4.1625 as the volumes of the remaining air under standard temperature and pressure. It will also be noted, that the expansion of air by 1° Fahrenheit increase of temperature, is assumed to be $\frac{1}{480}$th of its bulk at 32°. This is the received determination of Gay Lussac, Dalton, and Crichton. The more recent experiments of Rudberg, Magnus, and Regnault, concur in fixing it at about $\frac{1}{493}$d part of the same bulk. A few of the observations in this research have been calculated according to both these bases, but it will be seen that the differences thence resulting are practically unimportant.

It is proper to state, that, in calculating the bulk of air in the manometer, no account has been taken of the expansions of the tube itself; the reason of which is, that the quantity would have been too minute to be recognised in the observations. By the mean of ten determinations, by different experimenters, of the expansion of glass by heat, its increase in volume by an augmentation of 180° of heat is equal to $\frac{1}{394}$th part of its bulk at 32°; and this for 1° is $\frac{1}{70920}$th part. The highest temperature observed in the attached thermometer was 96°. Hence the proportion of the whole *apparent* volume of air, which could have been affected by this cause of error, must have been only $\frac{96-32}{.70920} = \frac{1}{1108}$th of its bulk at 32°; while, during the progress of the research, the *observations* took cognizance of no proportion less than $\frac{1}{993}$d part of the total volume; and for a great portion of the time it was but about five-ninths of this amount.

square inch, as at the very moderate pressures here employed, induce me to recommend its general adoption for steam vessels, as well as for stationary high-pressure steam boilers. For this purpose, it would probably be advisable to have the glass tube rise exactly 30 inches above the original level of mercury in the fountain. The volumes of air would then be measured in parts of an atmosphere, and would be, in every instance, the *complement* of the height of mercury observed.

As the manometer can be placed at any required distance from the boiler, it may always be made convenient for the inspection of the superintendent, or officer in command; an advantage seldom possessed by the common safety valve, or other apparatus for indicating the pressure of steam.

The barometer and thermometer being now regarded as indispensable to the navigator, will, of course, be constant accompaniments of the manometer.

7. Of the syphon, or water gauge, for indicating the draught of the chimney.

This apparatus is seen at *u*, fig. 2, plate II. It is composed of an inverted syphon of glass, with one end bent at right angles, to enter the chimney where the lower escape flue enters it. The other end is open to the external air. The first syphon used had an internal caliber of only 0.2 inch. Subsequently, however, another tube was substituted, having a bore of 0.45 inch in diameter. To the syphon was attached a scale divided into inches and tenths, for the purpose of observing the differences of level in the two limbs. The indications of this gauge represent the differences of pressure within and without the chimney, or the tendency of air to enter it. Water is about 837 times heavier than air; and, consequently, the numbers in the column of the tables headed "Height of water in syphon," multiplied by this number, give approximately the height of a column of air, which would balance the observed column of water. This is the *head of pressure of air*, under which air tended to enter the chimney in consequence of the rarefaction of the gases within, or the force of the jet of steam thrown into it from the boiler by the escape pipe E. Thus, when the difference of level in the two arms of the syphon was 0.3 inch, the *head of pressure of air* was $0.3 \times 837 = 251.1$ inches, or 20.92 feet. It is evident, however, that, as the motion in the flues is not that of cold air, but of air greatly rarefied, the same head of pressure will represent a far greater velocity than would be given by the same force to air of the mean density of the atmosphere. The draught of the chimney was dependent on three or four distinct causes: 1. The elevated temperature and consequent attenuation of the gases. This was occasionally as high as 400°, but generally below 300°, as will be observed in column of "Gases entering the chimney." 2. The jet of steam from the boiler. The gauge was always found to rise when the steam came to escape after taking the weights from the front safety valve, so as to throw a jet into the chimney. 3. The heat of the small furnace L, figs. 1 and 2, plate II. This furnace was used for some of the experiments with litharge, and was particularly beneficial in starting the fire, and giving a prompt action while heating up the boiler in the morning. 4. The prevalence of certain winds. Owing, probably, to the configura-

tion of the grounds, and the situation of the building in which the apparatus was placed, the prevalence of westerly or northwesterly winds was found to give a considerable augmentation to the force of draught. This is illustrated in table LXIX, in which, under the head of "remarks," it is stated that the wind was strong from the northwest, the syphon marked sometimes as high as .48 or .49 inch, while, on the four other days on which the same coal was burned, with the wind from other quarters, it seldom rose so high as .40 or .41 inch. It does not necessarily follow that the rate of combustion is proportioned to the mere force of draught as measured by the gauge. A variation in the thickness of the coal on the grate may present at one time far more obstruction to the passage of air than at another. The observations made by means of highly bituminous coal thrown suddenly on a bright mass of ignited coke, noting the time in which the smoke arrived at the top of the chimney, will serve to indicate the real velocity of current in the flues and chimney.

8. *Time in which smoke reached the chimney top.*

While the chimney was of the original height of 41 feet from the bottom, or 36 feet from the centre of the upper flue leading from the boiler, the trial of time occupied by the smoke in moving from the grate through the upper flue to the chimney top, on the 27th of May, gave as a mean result 21 seconds—the horizontal distance being 127 feet, and the vertical height 41 feet, or at the mean rate of 8 feet per second. The draught gauge stood on that day at a mean height, during steady action, of .2371 inch, and at a maximum of .25 inch.

After this trial, and previous to the 31st of May, the chimney was raised by the sheet-iron addition, 22 feet and ¾ of an inch. On that day, observations were again made on the rate of motion of smoke. It then took 15 seconds only for the smoke to perform the same circuits. The height of the draught gauge was then from .41 to .45 inch, or at a mean, during steady action, it was .4053; and the mean rate of motion was 12.66 feet per second—having now to travel 190 feet from the grate to the point of its final escape into the air.*

* The weight of a cubic foot of air at mean pressure and temperature is 523 grains; one cubic foot of water weighs 1,000 ounces avoirdupois; and mercury has a specific gravity of 13.568. By this relation, it appears that air is but $\frac{1}{837}$th part as heavy as water; and if the air were of equal density throughout, it would have a height of 27,807 feet. Under a head of 27,807 feet of its own mass, air would flow into a vacuum with a velocity of 1,338 feet per second. As the homogeneous atmosphere is equivalent to 407.04 inches of water, the velocities under the following heights in the syphon ought to be as follows, according to the well-known law which governs the movement of fluids:

Height of water in syphon.	*Velocity of flow.*	
.10 inch,	6.632	feet per second.
.15 "	8.122	"
.20 "	9.379	"
.25 "	10.486	"
.30 "	11.486	"
.35 "	12.407	"
.40 "	13.264	"
.45 "	14.068	"
.50 "	14.829	"
.55 "	15.563	"

The table referred to in the text above, will furnish many opportunities of ascertaining how nearly the calculated and the observed velocities approximate each other.

An extensive series of the observations made on this subject will be found at table CXCIII.

9. *On the measure of heating power.*

The practical measure of heating power, which I have adopted in the experiments mainly relied on in this research, and which, by way of distinction, is called *evaporative power*, is based on the known quantity of heat which water, raised to the boiling point, requires in order to convert it into steam.

This quantity I have taken to be 1,030° Fahrenheit, (572$\frac{2}{9}$ centigrade,) according to my own determination made some years since.*

It is obvious that, as all the varieties of fuel are referred to one and the same standard, it is not material to the justness of the comparison whether one determination or another of latent heat be adopted. I have preferred the one above mentioned, because I know exactly the means and precautions which were used in obtaining it.

10. *Of the corrections required in applying the standard for determining the relative evaporating powers of different coals.*

Having ascertained the number of pounds of water which have been supplied to the boiler during the continuance of the combustion of any known weight of coal, it might seem an easy problem to decide the evaporative power by dividing the former quantity by the latter.

Several circumstances, however, require to be considered, and their distinct effects computed, before we can arrive at a just conclusion.

1. The water delivered to the boiler was not always at the same temperature, and, consequently, different quantities of sensible heat were required to be added before it could begin to be converted into steam. The differences of temperature during the same day, and in the successive portions of water used in any one experiment, generally amounted to but a few degrees. But, in the course of nearly eight months, the extremes were 40 and 88°.

2. It frequently happened that the experiment was terminated by filling up the boiler with cold water after the fire had become extinct, and when, consequently, the temperature of the steam had fallen considerably below that due to the pressure generally maintained. In these cases, it is evident that the latter portions of the vaporization must have taken place from water already raised to the temperature of the steam itself, (generally about 230°,) instead of that of the water in the cistern, which was at some point within the limits above named. Hence it is necessary to calculate how much less water would have been evaporated, had the supplying of cold water continued till the heating power of the fuel was exhausted and the safety valve closed.

3. As the water supplied to the boiler at the conclusion of an experiment was *cold*, it often reduced the contents of the latter to a temperature below that at which the 0 on the water gauge had been adjusted; and, as it seldom happened that on two successive days the temperature of steam and water in the boiler at the beginning of experiment was exactly the

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* See Report on Strength of Materials for Steam Boilers.

same, it became necessary to ascertain the *expansion of water in iron*, in order to know when the requisite weight had been added. For this purpose many sets of observations were made on the gradual heating of the water from different low temperatures up to the usual point at which evaporation was carried on. These series of observations enabled me to ascertain that the same weight of water was in the boiler at the end as at the beginning of an experiment. This subject has already been treated of, while speaking of the boiler. The correction for differences of temperature of water in the boiler was further facilitated by many observations on the rise of water in the gauge by given weights supplied from the cistern.*

11. *Apparatus for testing the products of combustion.*

In order to form a tolerably correct judgment of the degree of perfection with which fuel is burned, and its available heat applied, it is necessary to study with attention the nature, condition, and properties of the products of combustion. Among the solid products are soot, or finely divided carbon, carbonate of ammonia, and sulphate of ammonia; all of which may be occasionally found coating the flues and chimney in greater or less quantities, according to the nature of the coal, and the mode of effecting its combustion.

Among the principal gaseous products are watery vapor, carbonic acid, and nitrogen mixed with unchanged atmospheric air. Not only is it necessary to determine whether the combustible parts of the fuel have been duly combined with oxygen of the air, and have thus produced their greatest heating effect, but also whether the air itself have found its way to the furnace in excess, and been heated at the expense of the fuel, without contributing anything to its useful effect.

In order to accomplish this purpose, the apparatus seen at *n*, *o*, *p*, *q*, *r*, A, fig. 1, plate II, and partly exhibited at *i* in the sectional fig. 1, plate III, was devised. This consisted of a wrought-iron tube *i*, penetrating to the flue at the point where the gases made their exit from the two in-

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* Having obtained the weight of water to 1 of coal, from the initial temperature, this quantity may be called w; the mean temperature at which it was delivered to the boiler, derived from the column of "*temperature of water in tank*," may be called t; for this temperature a co-efficient, derived from the experiments already referred to on the gradual heating of the water in the cistern, is applied, and may be represented by c; the corrected weight of water to 1 of coal will then be expressed by cw; the mean gain of sensible heat by the water in coming to the boiling point, will be expressed by $212°—t$. Let l be the latent heat of steam, which, by my own determination, (see Report on Strength of Materials for Steam Boilers,) is $=1,030°$; then will the total amount of heat received by the unit of water be expressed by $l+(212—t)$; and by the water evaporated by 1 of coal, $cw\times(l+(212—t))$. To know the weight of water which would have been evaporated, had it been delivered to the boiler at 212°, the above quantity is divided by l, giving the formula $cw+\frac{cw(212—t)}{l}$.

Having obtained a common standard of comparison for measuring the heating power of a given *weight* of coal, including all its ingredients, the efficiency of a given bulk of the same, (as of a cubic foot,) is obtained by multiplying the weight of such bulk by the value of the expression just given. To derive from the same the heating power of the unit weight of *combustible matter*, we deduct the wastage per cent. from 100. If the ratio of incombustible matter be represented by a, the water to 1 of combustible matter in the coal will be obtained by the formula $\frac{cw(l+(212—t))}{l(100—a)}$.

The last expression is useful in determining the relative values of different samples of coal from the same coal field; in which it often happens that the proportion of incombustible ingredients is very variable, while the composition of the combustible portion is nearly constant.

terior return flues. This tube passed through another of copper, permanently fixed in the wall of the furnace, and capable of being closed, when not required for drawing gas, by a suitable stopper of wood.

The iron tube had an enlargement consisting of about 4 inches of a musket barrel brazed to the smaller conducting tube. This enlargement was kept filled with asbestos moderately compacted together, but by no means precluding the passage of air. It served as a filter to strain from the gases collected all the solid impurities. With the exterior end of the small iron tube is connected, by a piece of gum-elastic tube, the glass tube and bulb *n*, (fig. 1, plate II,) filled with dried chloride of calcium, to arrest and absorb the moisture of the gas passing through it. But as this substance sometimes allows minute quantities of water to escape, a second tube, *o*, containing amianthus well moistened with concentrated sulphuric acid, was connected with the former, and served to render the gases perfectly dry.

These two tubes were placed near the furnace, that they might receive from the hot iron tube every portion of moisture without danger of being deposited in the leaden flexible tube which conveyed the gases to the next apparatus—that seen at *p*, which is a tube of Liebig, containing a strong solution of pure potash. Here the carbonic acid is absorbed, and the dry gas once more takes up a portion of moisture which the tube *q*, containing dry chloride of calcium, absorbs; allowing the gas in its dry state to arrive at the glass graduated jar *r*, inverted over mercury in a large well of the bath A, and suspended by a cord and counterweight, causing it to rise with any required degree of force necessary to draw the gas from the chimney.

The jar *r* contained about 190 cubic inches, and was furnished with a steel cap and stopcock, by which it was securely closed. A stopcock, interposed between the leaden tube and that containing potash, served to cut off the access of gas, and to test the accuracy of the joints interposed between it and the collecting jar, by raising the latter two or three inches out of the mercury, and ascertaining whether any air gained admittance. Like precautions were afterwards taken to ascertain that the joints near the furnace, connecting the potash and sulphuric acid tubes with the iron pipe *i*, (fig. 1, plate III,) and with the leaden tube, were all secure from leakage. The latter tube was 24 feet 5 inches long, one-fourth of an inch exterior, and one eighth of an inch interior diameter, and held 3.5 cubic inches. In the intervals of use, it was kept closed by the stopcock near the potash tube, and there was consequently little or no opportunity for the escape of the gas previously introduced.

The mercurial cistern had three "wells," or deep portions, which at the same time served for supports to the apparatus, and for receptacles of the jars containing the gases for analysis. It had also a horizontal trough, over which the re-agents could be passed up into the jars when required. When gas was to be drawn from the chimney, the large jar *r* was pressed into and completely filled with mercury, and its stopcock closed. The several glass tubes above referred to, containing the re-agents, were then carefully weighed, and their weights recorded. The potash tube and chloride tube, *p* and *q*, were then connected with the jar *r*, and with the stopcock *e*, (fig. 1, plate II;) after which, the soundness of the junctures was proved as above stated.

The other parts of the apparatus were then securely attached; and

finally the tightness of the whole series was tried before inserting the iron tube i (fig. 1, plate III) into its place. This was done by putting a sheet of gum elastic over the end of it, on which the thumb of one assistant was placed, while another opened the stopcocks at the jar, and raised it some distance out of the mercury. When all these precautions had proved the satisfactory condition of the apparatus, the iron tube was inserted in its place, and the drawing of gas commenced by opening the cocks near the jar, or was suspended by closing them, at pleasure. It was made more or less rapid by the amount of the counterweight P, and by the extent of opening of the stopcocks.

The time of commencing and discontinuing the drawing was noted, together with the amount of gas drawn; and the temperature of the air near the mercurial bath was indicated by a thermometer kept suspended there for the purpose. The barometer was generally noted either during or soon after the time of drawing gas. As soon as the drawing ceased, the several glass tubes with their contents were detached and re-weighed. The gain of weight in the chloride tube and sulphuric acid tube near the furnace, marked the weight of water collected; and that of the potash and chloride tubes near the jar r, indicated the weight of carbonic acid; the last re-agent being intended to withdraw from the gas the moisture taken up from the potash solution.

The height of the barometer being taken with every set of observations, served to determine the density of the gas drawn, of which the bulk was of course noted, after bringing the mercury within and without the jar to the same level. The amount of water due to the hygrometric state of the air passing to the furnace, was known by means of the two thermometers seen at e, e', (fig. 2, plate II,) placed at the entrance of the air port beneath the ash pit, the bulb of one of which was kept dry, and that of the other moist, by means of a cloth with which it was wrapped, and which was wetted after each set of observations. The dew point derived from observations on these two instruments was deduced from the table of the Encyclopedia Britannica, of which the general correctness was tested by several direct trials made during the progress of the research.

The dew point determines the weight of moisture in a given bulk of air, and the excess weighed in the apparatus was attributed to the products of combustion.

In the earlier experiments on this subject, the opening j (fig. 2, plate II) was used for inserting the gas-collecting tube, and during the operation required that the lower damper should be opened. This invariably accelerated, to some extent, the combustion and the rate of evaporation; and though it could not essentially vary the proportion of materials collected, did not afford so satisfactory a proof of the relation between the fuel burned, and of air by which its combustion was effected, as when afterwards the copper pipe expressly appropriated to this object, and seen at i, fig. 1, plate III, was inserted.

Having drawn into the jar r a sufficient quantity of gas, (usually from 80 to 100 cubic inches,) and ascertained its loss *in transitu* to the tubes above referred to, a portion was transferred to a smaller graduated jar s, with steel cap and stopcock, and was there tested for the amount of oxygen remaining. This was done by means of phosphorus passed up into the jar, and melted by bringing round the jar the curved jaws of a pair of tongs heated to redness.

The proportion of gas condensed after becoming cool marked the proportion of oxygen in the residual gas. The weight of carbonic acid determined its bulk at the temperature and pressure observed.*

The accompanying table CXCIV exhibits those experiments in which all the principal ingredients of the products of combustion were determined, and may illustrate the objects in view while prosecuting these researches. The first fifteen columns of the table are devoted to the data obtained by experiments, and noted in the column of "remarks" in the several tables of daily observations.

Following these are twelve columns exhibiting the relations to each other, both by weight and by bulk, of the chief products of combustion, calculated from the data furnished in the first division of the table.

The weight of water in 100 cubic inches of air, at the observed dew point, is first calculated from table CXCVI. This, applied with proper corrections to the quantity of gas which came to the apparatus, and deducted from the water collected in the experiment, furnished the second column of this part of the table; which, consequently, exhibits the weight of water derived from the combustion alone. From this, the bulk at standard temperature and pressure of the *oxygen* of that water, and the *weight* of its *hydrogen*, are readily calculated. The observed *weight* of carbonic acid gives the means of knowing the bulk of the oxygen, as well as the weight of the carbon which composed it. The condensation by phosphorus, with the observed temperature and pressure at the time the gas was drawn, affords the means of determining the bulk at a temperature of

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* Having the weight a in grains troy, of any quantity of carbonic acid, its bulk in cubic inches at a temperature of 60° and a pressure of 30 inches in the barometer, will be found by the formula $q = \frac{100a}{47.262}$ where q is the bulk required in cubic inches.

In order to bring all the observations to a common standard, it is of course necessary to bring into the calculation the temperature and pressure at which each specimen of gas was drawn into the jar.

If V be the observed column of dry gas taken into the jar, t the temperature at the time the drawing ceased, h the height of the barometer in inches at the same time, then would the bulk at 60°, under the same pressure, be $\frac{521V}{493+(t-32)}$. (This admits the expansion of air to be $\frac{1}{493}$ d part from 32°, for every degree Fahrenheit, according to the recent determinations of Rudberg, Regnault, and Magnus.) When the observed pressure is not equivalent to 30 inches at the standard temperature, it is corrected to bring it to that standard by the formula $h' = \frac{10018h}{9990+(t-32)}$, where h' is the corrected height of mercury which would have been observed at 60° under the same pressure. Hence, since the volumes are inversely as the compressing forces, $h' : 30 :: \frac{521V}{493+(t-32)} : V'$, where $V' =$ the true volume of dry gas at 60° and 30 inches barometer.

Since the bulk of carbonic acid is the same as that of the oxygen which enters into its composition, its relation to the total volume of dry gases, before arriving at the potash tube, is found by the ratio $\frac{q}{V'+q}$, which may represent the per centage of oxygen taken from the air, to constitute the carbonic acid.

As the treatment with phosphorus gave the ratio which the oxygen bore to the total amount of gas collected in the jar, this ratio may be called r; its bulk in cubic inches is known by taking the product rV', and its relation to the sum of dry gases will be $\frac{rV'}{V'+q}$. In these computations no account is taken of the phosphoric compounds.

As water contains eight ninths of its weight in oxygen, the bulk of the latter gas, belonging to any observed weight of water collected, is found by taking that fraction of the observed weight and dividing it by .341872, which is the weight in grains of one cubic inch of oxygen at 60° Fahrenheit and 30 inches barometer.

60°, and a pressure of 30 inches of mercury, of the residual gas (nitrogen) of the jar, as well as of the oxygen absorbed; and these, with the previously determined amount of carbonic acid, show the original volume of dry gases which arrived at the potash tube *p*, (fig. 1, plate II.) This volume is seen under the head of "total of dry gases collected." Following this, are three columns appropriated to exhibiting the ratio to the total of dry gases, first of the carbonic acid and of the residual oxygen separately, and then of their sum; in order to determine how nearly this latter relation approaches that of oxygen in pure atmospheric air. It will be observed that many of these numbers closely approximate to that relation as established by chemists, viz: 20[2] per cent. It will also be found that the average proportion of oxygen left in the air drawn into the jar was, by 71 trials on about 30 varieties of coal, 12.03 per cent. of that air, or 52.5 per cent. as much as would, with the same quantities of nitrogen, have constituted atmospheric air.

This result agrees pretty nearly with some which were obtained at the very time these experiments were in progress, by Mr. Robert Hunt,* from trials on several of the large Cornish engine furnaces. He found the condensation by potash to amount to one-ninth of the whole volume of gas drawn from the chimney; and of the remaining gas, one-tenth was condensed by phosphorus. My experiments also accord with what is stated by M. Peclet† relative to those made at Vesserling in 1832, from which it appeared that the quantity of oxygen found in the smoke of the chimney of a steam-boiler furnace, varied from 10.5 to 11.5 per cent. while using coal, and from 4.55 to 7 per cent. when burning wood. This author assumes in his calculations that one-half of the air which goes to the grate of a furnace using coal escapes unburnt.

The remaining thirteen columns of the table are consigned to deductions relative to the heating power of fuel. From a knowledge of the proportion of earthy matter in each coal, and of the carbon and hydrogen derived from its combustion, the quantity, in grains, of raw coal burned by the agency of the gases collected, is ascertained. From this, the *bulk* in cubic feet at standard temperature and pressure, and the weight in pounds of atmospheric air, sufficient to burn one pound of the raw coal, become known; and also, from the relation of the several gases collected, and their specific heats, the weight of air equivalent in specific heat to the dry gases for a pound of coal, is calculated, and is readily converted into *weight of water, equivalent in heat-absorbing power to that weight of air.* The water of combustion for one pound of fuel is calculated from the previously ascertained excess of that collected, above the hygrometric moisture; and the latter, for one pound of coal, is separately obtained from the bulk of air found necessary to burn a pound of coal, and from its observed dew point. The last five columns of figures in this division of the table are appropriated to recording the evaporative power of the several quantities of heat which were employed—1st, in raising the temperature of the air which supplied the combustion, from that at which it entered the air port, to that at which it reached the chimney; 2d, in vaporizing the water derived from the coal, and afterwards heating it to the tempera-

* See Practical Mechanics and Engineers' Magazine for December, 1843, page 93, article IV. Those experiments were made in June, August, and September, preceding their publication.

† Traité de la Chaleur, considérée dans ses applications: tom. i, p. 8.

ture at which it passed into the chimney; 3d, in raising the hygrometric moisture from its initial temperature to that possessed by the gases going into the chimney; 4th, and finally, that employed on the steam generated from the boiler at 212° by one pound of raw coal. The last column of numbers in the table is obtained by adding together the four immediately preceding.

12. *Apparatus employed in the ultimate analysis of coals.*

The section of an apparatus used for drying the specimens of coal analyzed, is seen in plate I, fig. 1. A is a copper boiler about 8 inches high, by 6 in diameter at the base, furnished with an interior cylinder B, about 5½ inches deep, and 3 inches in diameter, closed at bottom, and open at top to receive the small movable system of shelves *c*, on which are supported capsules, *b*, *b*, *b*, *b*, *b*, containing the pulverized coal to be dried. A lid, D, closes the mouth of the interior cylinder. A screw, N, closes steam tight the opening through which the boiler is filled. A tubulure, T, connected with a glass tube, *t*, bent at right angles, conveys the steam down to a distance of 3 feet, to a jar, E, containing mercury, into which the tube descends to a depth of about 5 inches. A basin to receive the condensed water which may flow from the surface of the mercury, serves as a support to this jar. A lamp, L, is placed beneath the boiler as it rests on the tripod S. Fig. 2 exhibits, on an enlarged scale, the frame of shelves *c*, withdrawn from the boiler. The arrangement above described enabled me to apply to the specimens a temperature of 216° for any desirable length of time; by leaving the lid D resting rather loosely over the mouth of the cylinder B, a certain amount of circulation of air was allowed, favoring the rapidity of the desiccation.

On the same plate, at fig. 3, is seen an arrangement for securing accuracy of junctures in connecting the successive parts of the apparatus employed in the analyses. A is the sheet-iron furnace; C the combustion tube, covered with thin sheet copper; and that with sheet iron firmly secured with thin iron wire. These precautions were found necessary, owing to the easy fusibility of American green glass tubes, which, without this safeguard, would generally give way under a heat much below what is desirable in analyzing coals.

P is a sheet-iron screen to shield the several tubes containing the absorbing apparatus from the heat of the furnace; *t* is the tube for chloride of calcium with its bulb, and having its beak entering a cork, which closes the mouth of the combustion tube C. To insure accuracy in this joint is not always of easy accomplishment. In using an exhausting syringe, or a common air pump, for this purpose, the number of joints in those instruments renders their indications rather equivocal. But the mercurial pump E answers this end perfectly. It is a glass jar about 1 foot high, and 2 inches in diameter, rather more than half filled with mercury. Into this liquid descends the inverted jar D, open at bottom, and drawn out above into a tube, the upper end of which is connected by the elastic joint *e*, with the tube B, about 3 feet in length, which is in turn united by the elastic tube *f*, with the chloride tube *t*. When the junctures are first made, the jar D is depressed so as to rest on the bottom of E. The mercury within and without D is then at the same level. By raising D, the mercury within it rises to the height say of *h*, while that exterior to it falls proportionally.

The distance m, h, then represents the column of mercury (which may be from 3 to 6 inches) that exerts its force to draw air into the combustion and chloride tube. A line encircling the jar at h serves as a marker to determine whether, when raised to that level, the mercury in D continues constant at the same height. A very few minutes determines this conclusively.

In detaching the pump, the joint e is not disturbed, nor the attachment of f to the tube B; so that a single tying only is required to connect it with the next piece of apparatus required to be tested.

Fig. 4 represents the apparatus at the conclusion of an experiment. The end of the combustion tube C, however, instead of projecting out of the furnace two or three inches, came only about one inch, or less, in front of the screen P. The limiting screen e, which during the progress of the combustion had been pushed successively from P to A in the furnace, is removed.

The upturned point of the combustion tube, as seen at C, fig. 3, has been broken off, to admit the passage of air through the tube; the calcium tube D, closed at bottom with a perforated cork, has been placed over the opening. A cork, fitting loosely at the upper end, allows air to pass freely down the tube, when, by the action of the pump H, air is drawn through the combustion tube, to sweep out the last portion of the products of combustion; t is a chloride of calcium tube; s a tube and bulb, containing amianthus moistened with concentrated sulphuric acid. L and L′ are Liebig's tubes, contaning concentrated solutions of potash; m is a calcium tube, to arrest the moisture taken up from the potash liquids; n is a tube for sulphuric acid and amianthus.

It will be understood that, during the progress of combustion, the leaden tube r was disconnected from the rest of the apparatus, and any gas not condensed by the re-agents made its escape at the beak of the tube n.

The glass tube I, descending into a jar containing mercury, served as a gauge to mark the force employed in drawing the gases through the apparatus. It may be proper to remark, that, in experiments in which chlorate of potash was placed at the bottom of the combustion tube, to drive out the products of combustion by means of the oxygen which it furnished when decomposed, the use of the air pump was unnecessary.

It is hardly necessary to state that each of the pieces of apparatus, t, s, L, L′, m, and n, was separately weighed in a delicate balance, both before and after the performance of every experiment, in order to obtain the exact gain of weight from absorbing the condensable products of combustion.

13. *On the hygrometric character of the different materials employed to produce the combustion of organic compounds, employed in this research.*

The chromate of lead has been recommended for this purpose, on account of its being absolutely destitute of all tendency to absorb moisture.

The oxide of copper precipitated from the nitrate, is well known to be a very active absorbent of water, rendering necessary all those minute and troublesome expedients to avoid excess of moisture, which are laid down in treatises on organic analysis.

The chlorate of potash is regarded as a dry salt destitute of hygrometric properties.

Having determined to make trial of finely pulverized oxide of copper,

procured from the sheet-copper manufactory, I first calcined 525 grains for more than an hour in an open muffle, to convert dinoxide into protoxide. This gave an increase of weight amounting to 32.82 grains, showing that 292.018 grains, or 55.62 per cent. of the whole, had received the requisite quantity of oxygen to effect that conversion.

After pulverizing completely the calcined oxide, a portion weighing 362 grains was placed in a porcelain crucible, with the same weight in another crucible of freshly ignited oxide, precipitated from the nitrate of copper. These were then placed side by side on a porcelain tile resting on a moistened cloth, and the whole covered with a half-gallon glass evaporating basin inverted over them. The moisture soon filled the interior of the basin, where the temperature ranged for 15½ hours from 45 to 60 degrees. The precipitated oxide had at the end of that time gained .61 grain, while the scale oxide had imbibed only .11 grain; or the former had absorbed 5.54 times as much as the latter. To compare chromate of lead with the oxide of copper, I put 250 grains of scale oxide, and the same weight of chromate of lead, into two separate crucibles; placed them in a muffle, and heated them nearly to redness. Each lost .08 grain. They were then placed under a basin over a damp cloth. Here they remained 24 hours surrounded with vapor which condensed copiously on the glass above them. By this exposure the crucible containing oxide of copper gained .18 grain, and that containing chromate of lead .48 grain, or nearly three times as much.

It appears that the moisture weighed on the cup containing scale oxide of copper, had been mostly attached to the cup itself; for, after standing 21 hours in an atmosphere at 40°, it had returned to its original weight, while the chromate of lead still retained an excess of .14 grain; fully proving that the latter material was more hygrometric than the former.

In a third trial, I put under a basin three cups, one containing scale oxide, one precipitated oxide of copper, and the third fused chromate of lead. Having all been exposed 48 hours in damp air under a basin, the scale oxide cup had received an increase of .09, the chromate of .16, and the precipitated oxide .22 grain.

The contents were removed from the several cups, and the latter thoroughly dried. When returned to them, it appeared that the scale oxide and chromate lost all their excess of weight by one hour's exposure on a table at a temperature of 60°, while the precipitated oxide still retained .12 grain of that excess.

It appears that these several powders had contained, when put under the basin, some portion of moisture; for, on exposing the three at a temperature a little below redness, for half an hour, the scale oxide lost .10 grain, the chromate .14, and the precipitated oxide .19 of a grain.

These cups were now loosely covered with their respective lids, to keep out dust, but not to prevent the ingress of air and its moisture; and in that condition left, for *one year*, exposed to the variable condition of air. It was then found that the scale oxide cup had gained .05 grain, the chromate cup .11, and the precipitated oxide .17; the second being more than *twice*, and the third more than three times as much as the first.

Of chromate of lead in its raw state, I put 154.66 grains into a small sand crucible, and brought it to incipient fusion. It lost 2.06 grains.

Of fused and subsequently pulverized chromate, I weighed into the same crucible 439.02 grains, heated it to incipient redness, when it was

found to have lost .22 grain. The crucible had been heated by itself just before this trial, and lost .1 grain.

I heated chlorate of potash to 390°, or to incipient fusion, by which it lost .808 per cent.

From all the foregoing experiments, I am led to the conclusion that scale oxide of copper is more free from tendency to absorb moisture than any of the other materials assayed, and that it absorbs with such extreme slowness as to be practically anhygrometric.

The above experiments, and the analysis which I made with the scale oxide of copper, having led me to give the preference to this oxide above that procured by precipitation, (contrary to the recommendation of every treatise which I have consulted on the subject,) I have been pleased to find that the conclusion I had formed respecting the utility of this material is in accordance with the practice of the great master of organic chemistry himself. A gentleman* who has spent some time in the laboratory of M. Liebig, has informed me that the scale oxide of copper produced in the sheet-copper manufactory, is the substance now employed at Giessen to produce the combustion of organic bodies. The reduction to the state of peroxide is there effected by moistening the scales with nitric acid and heating in an earthen crucible; some nitrate is formed, but is decomposed by subsequent ignition.

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CLASS I.

ANTHRACITES—NATURAL COKE—ARTIFICIAL COKE—MIXTURES.

SAMPLES.

No. 1. Beaver Meadow, slope No. 3.
2. Beaver Meadow, slope No. 5.
3. Forest improvement.
4. Peach mountain.
5. Lehigh.
6. Lackawanna.
7. Lyken's valley.
8. Beaver Meadow, (navy yard.)
9. Natural coke, (Virginia,)
10. Coke of Midlothian (Virginia) coal.
11. Coke of Neff's Cumberland coal.
12. Mixture $\frac{1}{5}$ Midlothian and $\frac{4}{5}$ Beaver Meadow.
13. Mixture $\frac{1}{5}$ Cumberland and $\frac{4}{5}$ Beaver Meadow.

General characters of the class.

The anthracites have specific gravities varying from 1.39 to 1.61; retain their form when exposed to a heat of ignition, and undergo no proper intumescence while parting with the small portion of volatile matter which they contain; or, if changed at all, are only disintegrated into angular fragments. Their flame is generally short, of a blue color, and consequently of little illuminating power. They are ignited with difficulty; give an intense concentrated heat; but generally become extinct while yet a considerable quantity remains unburnt on the grate.

No. 1.

Anthracite coal sent by the Beaver Meadow Railroad and Coal Company from the mine called "Slope No. 3" of said company.

This and the succeeding sample were accompanied by the following certificate:

"Office of Beaver Meadow Railroad and Coal Co.,
"*Philadelphia, June* 17, 1842.

"I certify that the (10 casks) coal were mined since last winter. Five casks, marked No. 3, are coals from our mine No. 3; and 5 casks, marked No. 5, are coals from our mine No. 5. There are but about two tons of each kind. Bristol, on the Delaware river, is the most convenient port for the delivery of it for shipment. We can have ready there large quantities of either kind, by giving due notice to this office.

"ROBERT PEARSALL,
"*President.*"

The state of this coal when received, (June 30, 1842,) as well as when burned, (June 30, 1843,) was that of lumps or masses of considerable magnitude—too large, indeed, to be either conveniently or profitably burned; and it consequently required to be broken up into fragments of such size as to be capable of a speedy and sustained ignition.

The aspect of the coal is generally characterized by an irregular fracture; a rather dull black color; a surface marked by minute striæ; and presenting, in many specimens, portions dotted with minute brilliant specks, which a close inspection shows to be composed of circles, or concentric rings, of which all the planes are parallel to each other. These marks of a definite internal structure can of course be seen in one position only on each of two opposite sides. The fracture is sometimes conchoidal and splintery. The surfaces of deposition are in general but faintly marked, until a partial combustion has developed them; they then become sufficiently apparent.

The specific gravity of two specimens was found to be 1.6104 and 1.6102; from which the calculated weight of a cubic foot of the solid coal, as it exists in the mine, is 100.645 pounds.

The mean result of forty experiments in measuring and weighing the coal as it came to hand, gave the weight of a cubic foot in its merchantable condition 54.925 pounds, or .5487 of the calculated weight just stated. Hence the space required to stow one gross ton of this coal is 40.78 cubic feet.

The two specimens of which the specific gravity is given above, were submitted to analysis: the first contained of moisture 1.005, and the second 1.296 per cent. These determinations were made by means of the apparatus seen at fig. 1, plate I, already described.

During the progress of experiments on evaporative power, 28 pounds of this coal were placed for twenty-four hours in the copper steam-drying bath K, (fig. 1, plate III,) where it was subjected to a temperature of rather more than 212°; and in that time it lost 7 ounces in weight, or 1.562 per cent. 100 grains of the second specimen above referred to, reduced to an impalpable powder, and treated with two drachms of concentrated pure nitric acid, and digested for twenty-four hours at a moderate sand heat,

filtered and treated with chloride of baryum, yielded of ignited sulphate of baryta .08 of a grain—equivalent to 0.011 per cent. of sulphur.

Of the same specimen, 20 grains treated with pure English litharge reduced 583.36 grains of metallic lead, or 29.168 times its own weight. A second trial gave 28.3 times its weight. (It seems probable that, in the latter case, some portions of the anthracite must have escaped complete reduction.)

Four trials on each of the two specimens, to determine the proportion of incombustible ingredients, resulted in giving for the first 10.91, 11.09, 11.14, and 11.05 per cent., or an average of 11.05; the weights employed being from 30 to 55 grains at each trial. For the second specimen, the numbers were 8.77, 8.79, 8 55, and 8.67, or an average of 8.69. The incineration was continued from 4 to 5 hours.

The ashes from analysis are of a grayish white color, tolerably dense, and tend to cohere slightly together into masses. By a reference to the following tables, it will be seen that the proportion of waste, including clinker and ashes, in the several trials of this anthracite, varied from 9.039 to 16.452 per cent. of the fuel burned. Taking the entire amount of coal actually consumed, 3,944.5 pounds, and the total weight of waste from the four trials, viz: 469.88 pounds, we find the per centage of the latter 11.912. The ratio of the clinker to the total waste was but 9.1 per cent., and the color and appearance of the substance such as to indicate but little tendency to fusion and vitrification in the earthy ingredients of this anthracite. No tendency to adhere to the grate bars was observed.

The ashes from the furnace are of a gray color, pretty abundantly mixed with particles of unburned anthracite. In trials of this, as well as other samples, it will be observed that the higher proportion of clinker was found after those experiments in which the combustion and evaporation had been most accelerated. Thus, in the 1st and 3d trials, in which the damper was drawn 10 inches, the ratios of clinker to ashes are 14.796 and 8.976; while in the 2d and 4th trials, with the damper set at 5 inches, the ratios are 6.5014 and 6.1315.

The weight of a cubic foot of the ashes of this coal was found to be 52.89 pounds, and of an equal bulk of its clinker 34.07 pounds. Of the dust from the flues, mixed with a little soot of the wood used in raising temperature at the commencement of each experiment, the weight was 21.39 pounds per cubic foot. The ashes, when exposed again to incineration for several hours on a platinum capsule, lost 44.33 per cent. of their weight, leaving a slightly reddish-gray powder. The ashes being 90.9 of the total waste, the reduction from burning out completely the combustible residuum is 40.295 per cent. of 11.912, or 4.8; leaving 7.112 as the true per centage of incombustible matter of this coal, exclusive of the dust of the flues, and showing that both the specimens above analyzed gave more than the average amount of earthy matter. Of soot and dust, only 3 lbs. and 14 ounces were collected on sweeping the flues after four days' burning; and of this small amount, 32.28 per cent. was combustible matter; leaving but 2⅝ lbs. of ashes attributable to the anthracite alone. The importance of this freedom from coating in the flues, is seen in the table of deductions, where, instead of finding a falling off in the "water from 212° to 1 of combustible matter of the fuel," we have the highest result at the fourth trial.

The volatile matter, other than moisture, was found to be only 2.335 and 2.234 per cent. in the two specimens analyzed; so that of the first,

the total volatile matter was 3.34, and in the second 3.52 per cent. Hence we have—

	1st specimen.	2d specimen.
Volatile matter - - - - - -	3.34	3.52
Earthy matter - - - - - -	11.05	8.72
Fixed carbon - - - - - -	85.61	87.76
	100	100

Admitting that the volatile matter above given is a fair average of that generally contained in this anthracite, and knowing from the trials of ashes already stated the true amount of earthy matter on a large scale, we have the following result:

Volatile matter (mean of two trials) =	3.430
Earthy matter (from 3,944.5 lbs.) =	7.112
Fixed carbon - - - - -	89.458
	100

It is proper to add, that four trials of volatile matter in specimens from this sample of coal by Dr. King, gave a mean of 4.462 per cent.; which, with the two above given, yielded a mean of 3.946, reducing the fixed carbon to 88.942.

The difficulty of ignition will be, in part, understood from the fact that the boiler was not in steady action in the first trial until 5 hours and 3 minutes after the charging with coal commenced. In the second trial, this time was increased to 5 hours and 43 minutes, notwithstanding that the first charge had been laid upon the grate before the fire of pine wood was commenced. In the third trial, the time was reduced to 2 hours and 45 minutes, having the same advantage of a charge of anthracite laid upon the grate before charging with wood. At the fourth trial, the time was farther reduced to 1 hour and 55 minutes. It appears, therefore, that the average length of time required to bring the furnace into full activity, after the kindling wood was withdrawn, was 3 hours and 52 minutes = 3.866 hours.

Another evidence of the difficulty of ignition is found in the table of deductions opposite to the title "pounds of coal withdrawn and separated after trial," which, on an average of the four trials, was 112⅞ lbs.

When broken to egg size, this coal gave, by three trials which were identical in their results, 57.25 lbs. per cubic foot.

Though it is well known that, in the anthracite coal districts of Pennsylvania, the materials there obtained from the mines are the only ones used by smiths for any of the purposes of their trade; yet as, among the numerous artisans of this class at the Washington navy yard, I could find none acquainted with its use in common forge fires, I was compelled to forego the experimenting which I should otherwise have felt it a duty to prosecute on this part of the subject. The adaptation of the particular kind of anthracite now under consideration to the purpose of working iron, either in close or hollow fires, cannot be doubted; provided the requisite experience and skill, and the proper arrangement for effecting the production and application of its heat, be brought into requisition.

The combustion of a portion of this anthracite in a well-constructed office grate, showed it to be rather more difficult of ignition than the (so called) red-ash coals. It is a fair type of the gray or white-ash anthracites of the eastern end of the southern and middle coal fields of Pennsylvania,

both in regard to exterior characters and general behaviour while undergoing combustion.

In the table of deductions, following those of the experiments, will be found a synopsis of the general results obtained in regard to its evaporative power. In that table are 47 lines—of which Nos. 2, 11, 12, and 25, are *approximations*, depending on the estimated weight of coal on the grate at the beginning and ending of "steady action" for the day; and Nos. 20, 21, 22, 23, and 25, are dependent on the observations respecting the height of water in the boiler at the same periods.

The following remarks apply generally to the tables of experiments:

The period of *steady pressure*, and that of *steady activity* of evaporation, are generally different—the former being usually longest. The dotted lines embracing the first of these periods, will be seen to commence on the left of the table, and include in their range the column of "*dew point, by calculation*," and that of the "*gain of temperature of air before reaching the grate.*" The lines denoting *steady pressure* commence at the column headed "*height of water in syphon*," and extend to the right of the table, with the exception of the two columns above mentioned. The numbers in the column of "*differences of temperature between steam and escaping gases*" will, in some instances, be found marked with the sign — before them, to signify that the escaping gases were then at a lower temperature than the steam; whereas when the sign + is used, or when the number is without any sign, the gases are indicated to have been hotter than the steam. In the column of "*remarks*" will be found noted the time when the water cistern was replenished. This serves to explain any irregularity which may happen to occur about the same time in the rate of supplying water to the boiler, which, as already noted, was necessarily suspended during the time of refilling. The same column contains such notes on the state of the atmosphere as were considered to have a bearing, more or less direct, on the other observations relative to combustion.

TABLE I.—BEAVER MEADOW

First trial—upper damper 10 *inches; air plates closed;*

						Of the							
						Water in tank.	Steam in boiler.	Height of barometer.	Height of manometer.	Volume of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.												
June 28	5.20	79	73	154	–	[illegible]	[illegible]	30.00	0.349	[illegible]	0.10	–	–
	6.27	79	73.5	160	232	85	222	30.00	[illegible]	5.64	[illegible]	–	99.25
	6.40	79	73.5	152	230	85	226	30.00	0.505	5.51	0.19	–	104.5
	7.25	80	74	152	225	85	228	29.99	0.513	5.44	0.21	–	–
	[illegible]	79	73	150	222	84	227	29.99	0.509	5.50	[illegible]	[illegible]	103.25
	8.30	80	73	152	220	85	228	29.98	0.515	5.42	0.20	–	–
	9.00	79.5	73.5	152	220	[illegible]	227	29.98	0.515	5.42	0.20	–	107.00
	[illegible]	80	74	154	216	[illegible]	229	29.99	0.549	5.08	0.21	–	–
	10.00	80	74	155	[illegible]	84	233	29.99	0.535	5.22	0.20	335	–
	10.30	80	74	160	[illegible]	84	230	29.99	0.521	5.36	0.24	595	–
	11.00	80	74	160	230	[illegible]	229	29.99	0.531	[illegible]	[illegible]	677	–
	11.30	80	74	168	246	84	229	29.99	0.533	5.24	0.28	1015	103.5
	P. M. 0.00	81	75	176	260	84	[illegible]	29.99	[illegible]	5.22	0.30	1180	–
	0.30	82	75	184	258	[illegible]	229	29.95	0.533	5.24	[illegible]	1520	–
	1.00	82.5	74.5	192	250	84	230	29.94	0.537	5.20	0.30	1895	93.
	2.00	[illegible]	74	212	260	84	230	29.93	0.533	5.24	0.30	2600	–
	2.30	86	74	218	270	[illegible]	[illegible]	29.92	[illegible]	5.24	0.30	3040	119.5
	3.00	86.5	74.5	226	280	84	232	29.92	0.550	[illegible]	0.34	3330	–
	3.40	86	75	244	278	84	232	29.91	0.554	5.04	0.42	3647	111.75
	4.10	87	76	258	270	86	230	29.91	0.527	5.30	0.28	[illegible]	100.25
	4.30	87	76	266	284	86	232	29.90	0.546	5.12	0.34	4715	–
	5.00	86	75	274	268	86	230	29.90	0.537	5.20	0.30	5299	–
	5.30	87	76	282	260	86	230	29.90	0.533	5.24	0.30	5394	–
	6.00	81	69	250	290	86	230	29.92	0.527	5.30	0.30	6361	[illegible]
	6.15	74	69	298	242	86	229	29.92	0.527	5.30	0.26	7189	–
	7.00	77	72	305	240	[illegible]	230	29.90	[illegible]	5.29	0.24	7189	–
	7.25	[illegible]	70	306	238	84	228	29.90	[illegible]	5.34	0.21	7654	–
June 29	A. M. 5.00	75	70	306	196	84	224	29.92	0.475	5.80	0.13	7654	–
	5.30	75	70	202	190	84	219	29.92	0.417	6.41	0.15	8301	–

Period of steady action to-day, from 11.30 a. m. to 5.40 p. m. = 6*h.* 10*m.* Coal supplied during that time 530.5 lbs.; water 4,912 lbs.; observations taken, 12 sets.

ANTHRACITE, FROM SLOPE No. 3.

steam thrown into chimney, and small furnace in action.

h. m.			Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour, in lbs.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
–	70.7	75	–	–	Water .06 inch above normal level; commenced firing.
6.27	71.4	71	+10	–	Consumed 147¼ lbs. wood; commenced charging with coal.
[illegible]	71.4	73	4		
–	71.7	[illegible]	— 3	–	Steam blowing off.
7.50	70.7	71	— 5	0.749	
–	70.9	72	— 8		
8.55	71.2	72.5	— 7	–	Wind SW., cloudy, with occasional showers.
–	71.7	74	—18	–	Front valve double weighted at 9h. 30m.; dew point by observation 71°.5.
–	71.7	75	+ 7	0.[illegible]	Second weight removed from front valve at 9h. 55m.
–	71.7	80	12	1.377	
–	71.7	80	21	0.434	
11.30	71.7	[illegible]	17	1.791	
–	72.8	96	30	0.874	
–	72.5	102	29	1.801	Sun shining; wind SW.
0.53	71.1	109.5	20	1 987	Commenced drawing gases at 0h. 53m.; drew in 12 minutes
–	70.0	127	30	1.867	100 cubic inches, which gave 0.72 grain water, 4.46 grains
2.30	69.7	132	39	2.331	of carbonic acid, and 15.15 cubic inches of oxygen; wind S.; some small coal in 7th charge.
–	71.8	141.5	[illegible]	[illegible]	Some fine coal in 8th charge.
3.23	71.2	[illegible]	46	1.259	Commenced filling tank; water in boiler 0.4 inch below normal level.
4.10	72.4	171	[illegible]	3.666	Filled tank at 4h.; at observation, water in boiler 0.3 inch below normal level.
–	72.4	179	52	2.988	Dew point, by observation at 4h. 10m., 72°.7.
–	71.2	188	38	[illegible]	Wind SE.; commenced drawing gases at 5h. 28m.; drew in 13 minutes 100 cubic inches, which gave 0.88 grain of
–	72.4	195	30	3.152	water, 5.68 grains carbonic acid, and 8.611 cubic inches of oxygen gas.
5.40	68.7	169	60	[illegible]	Commenced filling tank at 5h. 40m., concluded at 5h. 50m.; contents of ash pit thrown on grate at 5h. 45m.; wind
–	66.6	204	13		strong NW., with rain; water in boiler brought to 1.8
–	[illegible]	223	10	2.167	inch above normal level at 6h. 15m; damper reduced to 5
–	67.3	230	[illegible]		inches; water left at 1.1 inch above normal level.
–	67.7	131	—28	–	Fire on grate at 4h. 30m. a. m.; water in boiler 1.2 inch below normal level.
–	67.7	127	—28	–	Water adjusted for temperature.

RESIDUA.

	Pounds.
Coke - - - - - - - - - - - -	80.05
Ashes - - - - - - - - - - -	72.75
Clinker - - - - - - - - - - -	13.00
Ashes behind bridge - - - - - - - - - -	3.16
Total waste - - - - - - - - - - -	88.91
Deduct wood ashes - - - - - - - - - -	0.452
Total waste from coal - - - - - - - - - -	88.458

TABLE II.—BEAVER MEADOW

Second trial—upper damper 5 inches open; air plates closed;

Date.	Hour.	Temperatures of the Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of coal supplied to grate.
	h. m. A. M.												
June 29	5.30	75	70	202	190	84	218	29.92	0.416	6.41	0.15	-	115.25
	6.15	77	71.5	185	204	84	226	29.93	0.521	5.38	0.17	-	105.00
	6.55	77	72	174	230	84	229	29.96	0.527	5.30	0.20	-	100.50
	7.30	77	71	172	208	84	227	29.96	0.501	5.56	0.28	-	-
	8.00	78	72	170	204	84	226	29.96	0.501	5.56	0.18	-	-
	8.30	80	75	160	-	84	227	29.96	0.507	5.50	0.18	-	-
	9.00	81	75	168	-	84	226	29.96	0.493	5.64	0.16	-	-
	10.30	84	74	160	-	84	228	29.95	0.518	5.40	0.18	-	-
	11.00	85	74	160	-	84	229	29.94	0.540	5.18	0.18	163	-
	11.30	86	74	160	222	84	232	29.93	0.530	5.28	-	-	115.50
	P. M.												
	0.00	86	74	160	232	83	228	29.92	0.517	5.40	0.20	420	-
	0.30	86	74	168	232	83	228	29.92	0.521	5.36	0.25	-	-
	1.00	87	74	174	252	84	234	29.92	0.538	5.20	0.30	575	106.25
	1.40	89	75	182	240	84	229	29.92	0.525	5.32	0.28	958	-
	2.30	91	73	190	232	84	230	29.91	0.521	5.36	0.28	1128	116.00
	3.00	90	75	206	241	84	230	29.91	0.530	5.28	0.30	1378	-
	3.30	90	75	208	250	84	231	29.89	0.540	5.17	0.37	1810	-
	4.10	91	77	218	250	86	230	29.89	0.520	5.37	0.30	2788	114.75
	5.15	91	75	254	252	88	230	29.89	0.530	5.28	0.33	3686	99.00
	5.45	90	77	260	242	88	230	29.89	0.538	5.20	0.34	4014	-
	6.00	91	78	270	240	88	230	29.90	0.530	5.28	0.31	4266	119.00
	6.30	87	77	282	232	88	230	29.91	0.535	5.22	0.30	4489	-
	6.55	88	77	294	240	88	230	29.91	0.531	5.26	0.22	4664	-
	7.10	88	78	308	226	88	228	29.92	0.510	5.47	0.18	5507	-
	10.00	84	76	292	230	87	228	29.92	0.516	5.40	0.20	6414	-
	A. M.												
June 30	5.10	81	73	236	190	86	226	29.97	0.496	5.60	0.19	6419	-
	5.40	79	71	260	198	86	220	29.99	0.426	6.30	0.20	6931	-

Period of steady action from 1 p. m. to 5.55 p. m.=4 *h.* 55*m.*; water supplied, 3,607 lbs.; coal, during same period, 448.75 lbs.; observations taken, 8 sets; hence, water to 1 of coal, during steady action, is 8.037, (final result, 7.983.)

ANTHRACITE, FROM SLOPE No. 3.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour, in lbs.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
h. m.					First charge thrown on back of grate; commenced firing at 5*h.* 30*m.* a. m.
5.30	67.7	127	—28	-	Water 0.15 inch above normal level; consumed 124¼ lbs. of wood.
6.15	68.4	108	—22	-	Steam at equilibrium; an additional weight on safety valve.
6.55	69.9	97	+ 1	-	Additional weight on safety valve removed; steam blows off;
-	68.4	95	—19		lower damper now closed.
-	69.5	92	—22	-	Lower damper again opened.
-	73.2	80	-	-	Dew point, by observation, 69°.8; at same place, by calculation, 70°.
-	72.8	87	-	-	Steam fallen too low to blow off.
	....	......			
-	70.4	76	-	-	Steam blowing off; wind SW., brisk; sky clear.
-	70.0	75			
11.30	69.7	74	—10	-	Lower damper closed; very large lumps in 4th charge of coal.
-	69.7	74	+ 4	0.681	
-	69.7	82	4		
1.00	69.4	87	18	0.411	
....			....	....	
-	70.3	93	11	1.517	
2.30	66.5	99	2	0.540	Dew point, by observation, 68°; at same place, by calculation, 68°.9.
-	70.0	116	11	1.326	Commenced drawing gases at 3*h.* 8*m.*; drew in 21 minutes 100 cubic inches, which gave 0.75 grain of water,
-	70.0	118	19	2.288	5.46 grains of carbonic acid, and 12.88 cubic inches of oxygen.
3.53	72.7	127	20	3.091	Tank partly filled; commenced drawing gases at 5*h.* 1*m.*
5.00	69.7	163	22	2.194	p. m.; drew in 8 minutes 100 cubic inches, which gave 0.57 grain of water, and 4.39 grains of carbonic acid.
-	73.0	170	12	1.738	Filled tank.
5.55	74.0	179	10	2.670	
....			....	....	
-	73.8	195	2	1.181	
-	73.8	206	10	1.112	Contents of ash pit thrown on grate.
	....	......			
-	74.9	220	— 2	-	Water left in boiler 1.9 inch above normal level; after filling up, water at usual working level.
-	73.3	208	+ 2	1.503	
-	70.0	155	—36	-	At 4*h.* 40*m.*, temperature of water 228° and 1.3 inch below normal level.
-	67.6	181	—22	-	Water adjusted for temperature.

RESIDUA.

	Pounds.
Coke	134.25
Clinker	7.00
Ashes	98.23
Ashes behind bridge	2.80
Total	108.03
Deduct wood ashes	0.381
Total waste of coal	107.6[illegible]

TABLE III.—BEAVER MEADOW

Third trial—upper damper 10 inches open;

										Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	[illegible]								86	6.30	0.20	–	[illegible]
	6.00	80	73	222	–	86	226	29.99	0.547	5.03	0.23	–	[illegible]
	6.30	[illegible]	72	214	–	86	227	30.01	0.603	4.55	[illegible]	–	106.00
	7 00	81	72	208	220	86	228	30.03	0.500	5.56	0.23	248	[illegible]
	7.30	83	72	206	230	86	228	30.03	0.520	5.37	0.24	–	–
	8.00	83	[illegible]	208	242	86	229	30.03	0.520	5.37	0.24	383	–
	8.30	[illegible]	72	212	254	86	230	30.02	0.537	5.20	[illegible]	560	–
	9.00	84	72	220	252	86	[illegible]	30.02	0.533	[illegible]	0.26	993	[illegible]
	10.15	84	71.5	240	[illegible]	82	230	30.03	0.535	5.22	0.26	1642	107.50
	10.45	87	73	246	262	82	230	30.01	0.533	5.24	0.28	2269	–
	11.15	[illegible]	73	254	270	82	231	[illegible]	0.536	5.22	[illegible]	2690	121.00
	11.45	88	73	260	280	82	[illegible]	[illegible]	0.536	5.22	[illegible]	[illegible]	–
	P. M.												
	0.15	88	73	286	278	82	231	30.01	0.541	5.16	[illegible]	–	–
	0.45	89	73	274	270	82	230	30.01	0.533	[illegible]	[illegible]	4100	110.00
	1.15	89	74	286	270	82	[illegible]	30.02	0.537	5.20	0.32	4512	98.25
	1.50	90	75	296	[illegible]	82	230	30.01	[illegible]	5.14	0.32	5000	–
	3.10	95	76	304	260	86	230	[illegible]	0.535	[illegible]	[illegible]	6160	[illegible]
	3.50	91	[illegible]	310	[illegible]	86	231	[illegible]	0.540	5.17	0.31	[illegible]	–
	4.20	92	75	314	260	86	230	30.00	0.537	[illegible]	0.30	7206	106.75
	4.45	92	77	320	280	86	230	30 00	0.558	5.00	[illegible]	7555	–
	5.15	[illegible]	78	340	230	86	229	30.01	0.505	5.52	[illegible]	8037	–
	A. M.												
July 1	5.10	83	[illegible]	[illegible]	190	[illegible]	226	30.02	0.503	5.54	–	–	–
	6.00	83	76	232	186	[illegible]	216	30.04	0.385	6.70	0.14	9247	–

The period of steady action to day is from 8*h.* 45*m.* a. m. to 4*h.* p. m.; coal supplied, 657 lbs.; water supplied to boiler in the same period, 6,103 lbs.

ANTHRACITE, FROM SLOPE No. 3.

air plates open, and steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.			Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
h. m.					First charge of coal thrown on grate behind kindling wood.
5.40	67.6	131	—22	-	Water 0.2 inch above normal level; commenced firing.
6.00	70.3	142	-	-	Consumed 66¾ lbs. of wood; steam blows off under single weight; put on a second weight; removed second weight from valve at 6*h.* 30*m.*
6.30	[illegible]	134			
7.00	68.4	127	— 8	1.314	The third charge of coal reduced to egg size, required 8½ pounds more to be added (=114½ pounds) to fill charge box.
-	67.7	128	+ 2		
-	67.7	125	15	0.225	
-	67.7	[illegible]	24	0.985	
8.45	67.3	166	22	2.294	Wind NW., clear; air plates opened.
9.10	66.0	136	40	1.926	Dew point, by observation, 66°.
-	67.9	159	32	2.257	
11.15	67.5	166	39	2.226	The seventh charge of coal, composed of large lumps, on being reduced to egg size, left a surplus of 6½ pounds after refilling charge box: making the weight of a charge of this size, (as before,) 114½ lbs.
-	67.5	172	50	2.967	
-	67.5	166	47		
[illegible]	67.2	165	40	2.252	
1.00	68.8	197	[illegible]	2.162	
-	70.0	206	50	2.216	
2.40	70.0	209	30	2.806	Filled tank at 2*h.* 55*m.* p. m.
-	69.7	219	44	[illegible]	
[illegible]	[illegible]	222	50	3.060	
-	[illegible]	227	50	[illegible]	Air plates closed; contents of ash pit thrown on grate; valves double weighted.
-	73.3	246	1	-	Water in boiler left at 2.2 inches above normal level.
-	73.6	167	—30	-	Fire still on grate; steam at equilibrium, and water in boiler at 2.4 inches below normal level.
-	73.4	149	—30	-	Water in boiler adjusted for temperature.

RESIDUA.

	Pounds.
Coke - - - - - - - - - -	103.75
Clinker - - - - - - - - - -	9.50
Ashes - - - - - - - - - -	[illegible]
Ashes behind bridge - - - - - - - - -	3.52
Total waste - - - - - - - - - -	105.77
Deduct wood ashes - - - - - - - - -	0.266
Total waste from coal - - - - - - - - -	105.504

TABLE IV.—BEAVER MEADOW

Fourth trial—upper damper 5 inches open; air plates open;

												Weight of water supplied to boiler.	Weight of charges of coal.
July 1	6.00	[illegible]	76	232	186	[illegible]	216	30.04	0.366	6.70	0.14	–	128.25
	6.25	82	74	220	–	86	226	[illegible]	0.515	[illegible]	0.20	–	110.25
	7.15	83	75	212	200	86	230	30.05	0.527	[illegible]	[illegible]	262	128.75
	[illegible]	87	79	226	240	82	230	[illegible]	0.527	5.30	0.26	[illegible]	–
	8.30	86	78	234	230	82	[illegible]	30.04	0.525	5.32	0.25	990	112.50
	9.00	87	79	238	[illegible]	82	230	30.04	0.529	5.18	0.26	1240	–
	9.30	88	79	246	260	82	230	30.04	[illegible]	5.12	0.30	1580	118.50
	10.15	90	80	254	252	82	230	[illegible]	0.537	5.20	0.30	2082	–
	10.45	93	80	256	248	82	230	30.06	[illegible]	5.30	[illegible]	2488	[illegible]
	11.15	96	80	274	244	82	230	30.06	0.520	[illegible]	[illegible]	2993	–
	11.45	95	[illegible]	280	256	[illegible]	230	30.06	0.532	5.25	0.28	3336	114.50
	P. M.												
	0.15	94	81	[illegible]	[illegible]	83	230	30.05	0.535	[illegible]	[illegible]	3725	–
	0.45	[illegible]	80	[illegible]	[illegible]	[illegible]	230	[illegible]	[illegible]	5.20	[illegible]	[illegible]	100.75
	1.35	[illegible]	80	312	[illegible]	86	230	30.04	0.535	5.72	[illegible]	4776	120.50
	2.00	95	86	312	274	86	[illegible]	30.03	0.543	[illegible]	0.35	–	·
	3.20	100	86	[illegible]	255	88	238	30.02	[illegible]	4.22	0.25	6352	126.75
	3.50	99	87	370	230	90	232	[illegible]	0.529	5.29	0.26	6740	–
	4.05	101	86	374	222	90	229	30.00	[illegible]	5.56	0.25	[illegible]	–
	A. M.												
July 2	6.15	87	81	[illegible]	165	89	226	29.91	[illegible]	5.64	0.16	[illegible]	–
	6.50	[illegible]	81	–	–	89	216	29.90	0.373	[illegible]	–	8522	–

Period of steady action, from 8*h.* 20*m.* a. m. to 2*h.* 45*m.* p. m.=6*h.* 25*m.* Coal supplied, 697.25 lbs.; water, 4,942 lbs.; water to 1 of coal for this period, 7.059.

ANTHRACITE, FROM SLOPE No. 3.

steam thrown into chimney, and small furnace in action.

4.00	73.6	149	—30	-	Water in boiler 0.15 inch above normal level. Commenced firing.
6.35	71.0	188	-	-	Wood consumed, 89 lbs.; steam blowing off.
6.35	72.2	129	—30	0.604	The first charge of coal was composed of large lumps mixed with fine.
-	76.6	139	+10	1.822	Filled tank, and air plates opened at 7*h*. 55*m*. a. m.
8.20	75.5	148	± 0	1.801	
-	75.2	161	+14	1.325	The fifth charge of coal (composed of large lumps) reduced to egg size, gave 114½ lbs. to 2 cubic feet.
9.05	76.3	158	30	1.271	Wind S., light; dew point, by observation, 77°; by calculation, at same place, 77°.2.
-	77.2	164	22	1.773	Wind NE.; clear.
10.40	76.4	163	18	2.151	
-	75.7	178	14	2.675	Wind E., light; clear, or with slight haziness.
11.45	77.3	185	26	1.812	28 lbs. of this coal put this day in drying apparatus, weighed (July 8) 27 lbs. 10 oz.
-	77.5	194	18	2.066	
0.50	76.1	200	20	2.305	
1.35	77.4	223	20	1.965	
-	84.0	217	42	-	Pavement just sprinkled with water. Dew point, by observation, 76°; by calculation, at same place, 75°.4; filled tank at 2*h*. 55*m*.; valves doubly weighted, and air plates closed at 3*h*. 20*m*.; filled tank, contents of ash pit thrown on grate, and extra weight removed from valves at 3*h*. 40*m*. p. m.; temperature of open air at 3*h*. 50*m*., 97°. Dew point, by observation at same place, 74°. 9th charge of coal, large lumps with fine; 10th charge, same.
2.45	82.9	244	17	2.383	
-	84.4	271	— 2	2.056	
-	84.0	273	— 7	-	Water in boiler left at 1.1 inch above normal level.
-	79.3	137	—41	-	Water in boiler 2.65 inches below normal level. Fire still in grate.
-	79.1	-	-	-	Water adjusted.

RESIDUA.

	Pounds.
Coke	181.00
Clinker	10.50
Ashes	157.75
Ashes behind bridge	3.27
Total ashes and clinker	171.52
Deduct wood ashes	0.273
Total waste from coal	171.247
Soot from flues	3 lbs. 14 oz.

TABLE V.—DEDUCTIONS

Experiments on Beaver Meadow

	Nature of the data furnished by the respective tables.	1st Trial. (*Table I.*)	2d Trial. (*Table II.*)
		June 28.	*June 29.*
1	Total duration of the experiment, in hours	24.167	24.167
2	Duration of steady action, in hours	6.167	4.917
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	10	9
7	Total weight of coal supplied to grate, in pounds	1048.	991.25
8	Pounds of coal actually consumed	967.5	857.
9	Pounds of coal withdrawn and separated after trial	80.5	134.24
10	Mean weight, in pounds, of one cubic foot of coal	52.4	55.068
11	Pounds of coal supplied per hour, during steady action	86.026	91.27
12	Pounds of coal per square foot of grate surface, per hour	6.114	6.487
13	Total waste, ashes and clinker, from 100 pounds of coal	9.039	12.563
14	Pounds of clinker alone, from 100 pounds of coal	1.3375	0.8168
15	Ratio of clinker to the total waste, per cent.	14.796	6.5014
16	Total pounds of water supplied to the boiler	8301.	6981.
17	Mean temperature of water, in degrees Fahrenheit	84°.8	86°.6
18	Pounds of water supplied at the end of experiment, to restore level	647.	712.
19	Deduction for temperature of water supplied at end of experiment, in pounds	81.	89.
20	Pounds of water evaporated per hour, during steady action	796.53	733.62
21	Cubic feet of water per hour, during steady action	12.744	11.738
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.11	1.948
23	Pounds of water per square foot, by a mean of several observations	2.213	1.92
24	Water evaporated by 1 of coal, from initial temp. (a) final result	8.496	7.9836
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	9.259	8.037
26	Pounds of fuel evaporating one cubic foot of water	7.3564	7.8286
27	Mean temperature of air entering below ash pit, during steady pressure	83°.73	88°.25
28	Mean temperature of wet bulb thermom., during steady pressure	74°.73	75°.19
29	Mean temperature of air on arriving at the grate	211°.8	209°.12
30	Mean temperature of gases when arriving at the chimney	261°.07	239°.78
31	Mean temperature of steam in the boiler	238°.47	229°.94
32	Mean temperature of attached thermometer	80°.08	84°.5
33	Mean height of barometer, in inches	29.941	29.912
34	Mean number of volumes of air in manometer	5.213	5.219
35	Mean height of mercury in manometer, in atmospheres	.5338	.5275
36	Mean height of water in syphon draught gauge, in inches	.3145	.3137
37	Mean temperature of dew point, by calculation	71°.62	70°.86
38	Mean gain of temperature by the air, before reaching grate	128°.07	120°.87
39	Mean difference between steam and escaping gases	36°.54	13°.37
40	Water to 1 of coal, corrected for temperature of water in cistern	8.4599	7.9482
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.5029	8.9128
42	Pounds of water, from 212°, to one cubic foot of coal	497.93	490.81
43	Water, from 212°, to one pound of combustible matter of the fuel	10.4472	10.1934
44	Mean pressure, in atmospheres, above a vacuum	1.4185	1.4051
45	Mean pressure, in pounds per square inch, above atmosphere	6.1812	5.9823
46	Condition of the air plates at the furnace bridge	Closed.	Closed.
47	Inches opening of damper, (U. upper, L. lower)	U. 10	U. 5

FROM TABLES I, II, III, IV.

anthracite coal, from slope No. 3.

3d Trial. (*Table III.*)	4th Trial. (*Table IV.*)	Averages.	Remarks.
June 30.	*July* 1.		
24.333	26.833		
7.25'	6.417		
14.07	14.07		
377.5	377.5		
18.75	18.75		
11	10		
1182.75	1172.		
1079.	1041.		
103.75	131.	112.37	When the damper was open 10 inches, the coal left unburnt was at a mean of 92.12 lbs.; when at 5 inches, it was 132.62 lbs.
53.761	58.6	54.957	
90.62	108.67	94.1465	The data for this line will be found at the bottom of each table of experiments.
6.441	7.723	6.691	
9.778	16.452	11.958	
0.8850	1.0086	1.012	
8.976	6.1315	9.1012	
9247.	8522.		
84°.3	85°.2		
1210.	1310.		
151.	160.		
841.79	771.82	785.94	See notes at the foot in tables of experiments, for the data.
13.467	12.34	12.572	These numbers are derived from those next above them, by dividing by 62.5.
2.2299	2.044	2.0817	These numbers are obtained by dividing those of line 20 by those of line 4.
8.2483	1.959		
8.43	8.0326	8.2355	
9.289	7.059	8.411	
7.414	7.7808	7.595	
88°.31	90°.54		
72°.5	79°.77		
269°.38	263°.54	238°.46	
269°.31	245°.85	254°.002	
230°.28	230°.15		
82°.44	83°.13	–	These temperatures are approximations only, from observations taken at the mouth of the air port, and reduced in accordance with subsequent observations.
30.013	30.049		
5.213	5.233		
.5365	.5338		
.3072	.386	.3303	
68°.19	76°.72		
181°.07	173°.	150°.752	
42°.	22°.	28°.48	
8.3942	7.9984	8.2002	
9.4290	8.9846	9.2073	
506.92	526.5	505.54	
10.4519	10.7538	10.4616	
1.4252	1.4228	1.4179	
6.2789	6.2434	6.1715	
Open.	Open.	–	From the numbers in line 43, it appears that the two days' combustion with open air plates, gave results higher than those with the same plates closed.
U. 10	U. 5		

Explanation of the table of deductions.

In explanation of the preceding, and all the similar tables of deductions which occur in this report, it may be stated, that the 1st line, "*Total duration of experiment, in hours*," refers to the time when the fire was lighted to commence the experiment, to that at which the level of water in the boiler had been adjusted, and the last set of observations recorded. It will often be found that the moment of ending one experiment is that of commencing the next; and that, in fact, the same set of observations served for both. The 2d line, "*Duration of steady action, in hours*," is a period selected for the comparison of various related quantities requiring consideration in treating of combustion and evaporation. The determination of this period was generally fixed by an examination of the 19th column of each table, in which the water evaporated per square foot of absorbing surface is given. This period is assumed from the time that some one of the charges of coal had been all placed upon the grate. The 3d line is devoted to recording the "*area of the grate, in square feet*," during each trial. In general, it remained the same for all the trials of the same sample, but occasionally varied, even while trying the same coal. The 4th line denotes the area of the boiler and its flues exposed to the fire, or to the current of flame and hot gas passing from the furnace to the chimney. "*The area of boiler exposed to direct radiation*," is intended to denote only that part of the lower arch of the boiler which was directly above the fuel on the grate. The 6th, 7th, 8th, and 9th lines explain themselves. *The mean weight in pounds* of one cubic foot of coal, is in all cases found by dividing the total weight of all the charges recorded, by double their number.

At the bottom of each table of experiments will be found a statement of the coal supplied during the period of steady action. That weight divided by the length of that period in hours, as contained in the 2d line of the table of deductions, gives the 11th line, viz: *pounds of coal supplied per hour during steady action*; and the latter again divided by the number in the 3d line, affords that in the 12th line, or the *pounds of coal per square foot of grate surface per hour*. The whole amount of ashes and clinker contained in the remarks at the foot of each table of experiments, divided by the number in the 8th line, gives the per centage of waste entered in the 13th line of deductions. The weight of clinker alone, divided by the weight of coal actually consumed, gives the number in the 14th line. The number in the 14th divided by that in the 13th line, gives the *ratio of clinker to the total waste* contained in the 15th. The numbers of the 16th line are derived from the last number in the 13th column—that which records the *weight of water supplied to the boiler*, in each of the experimental tables. The 17th line is derived from the 6th column of the experimental tables, "*temperature of water in tank*," by dividing the sum of the numbers between the horizontal dotted lines crossing that column, by the number of observations recorded within the *period of steady pressure*, which those dotted lines are intended to indicate. The *pounds of water supplied at the end of experiment to restore level*, in the 18th line, are known from the difference between the number in the 16th line, and that which in the table of experiments belongs to the last set of observations on the preceding day. Thus, in table I, we have the last number in the

column of "weights of water supplied to boiler," 8,801 pounds recorded on the morning of the 29th of June, and the last number entered on the preceding evening 7,654. The difference of these, 647, will be found as the first number in the 18th line of the table of deductions. The 19th line contains the calculated reduction which ought to be made on account of the last portion of water having been evaporated from the temperature of 230°, instead of the mean temperature of water in tank, as found in the 17th line. This reduction is found by multiplying the weight of water supplied to restore the level, by the difference just mentioned, and dividing by the sum of the sensible and latent heat of steam produced from water of the temperature observed in the tank. Thus, $647 \times (230-84) \div 1154 = 81+$; and this latter is the number under the first trial in the 19th line of deductions.

The water supplied to the boiler during steady action, found in the column of "remarks" of the tables of experiment, divided by the numbers in the 2d line, gives that in the 20th; and the latter, divided by 62.5, (the weight, in pounds, of one cubic foot of water,) gives the number in the 21st line—"*cubic feet of water per hour during steady action.*" The number of the 20th line, divided by that of the 4th, (*area of heated surface,*) gives the number in the 22d line. The 23d line is derived from the 19th column of the experimental table, by taking the mean of the numbers embraced between the horizontal dotted lines, which there include the *period of steady activity* of the boiler, not merely that of *steady pressure,* as above designated. It will be observed that the numbers in the 22d and those in the 23d line do not always coincide. This may be accounted for by the fact, that the time elapsed between two consecutive observations is not always the same during the period of steady action. The difference between the numbers in lines 16 and 19, divided by that in line 8, gives the number in line 24, viz: *water* evaporated by one of coal from initial temperature, which is the "final result" of the day's operations, subject only to a slight correction hereafter to be noticed, (line 40.) The number in the 25th line is derived from a division of the 20th by the 11th. It is, of course, like all the other numbers, dependent on the observation of the mass of coal at any moment on the grate—only an approximation, more or less near, to the preceding line. It is useful in determining what reliance is to be placed on the other deductions depending on the same observation. In comparing the averages in 42 tables of deductions, it will be found that in 23 cases, lines 24, or the "final results," are higher than lines 25, or results during "steady action;" and that 19 cases of the reverse occur. The total of the averages on lines numbered 24 is 327.82
On those numbered 25 is - - - - - - 322.90

The difference of which - - - - - - 4.92,
is 1.5 per cent. of the upper number. The total weight of coal consumed, divided by the total weight of water evaporated, reduced to cubic feet, gives the number in the 26th line. The mean of the numbers included in the 2d column of the experiment table, between the dotted lines limiting the period of steady pressure, furnishes the number in line 27th; column 3d furnishes in a similar manner the number in line 28th; column 4th gives *line* 29th; column 5th, line 30th; column 7th, line 31st; column 8th, line 32d; column 9th, line 33d column 11th, line 34th; col-

umn 10th, line 35th; column 12th, line 36th. In this last case, it is the period of *steady action* which is limited by the horizontal dotted lines; not that of *steady pressure*, as in several of the preceding. Line 37th is derived by taking the mean of the numbers between the dotted lines in column 16th; line 38th, in a similar manner from column 17th; and line 39th, from column 18th, as limited by the dotted line of steady action. Line 40 is obtained by multiplying the number in line 24 by the co-efficient of expansion of water (as given in a preceding part of this report) for the mean temperature, as contained in line 17th. The number in line 41 is found by multiplying that in line 40 by the sum of the sensible and latent heat imparted to the water, and dividing by the latent heat of steam at 212°. The number in the 41st line, multiplied by that in the 10th, gives the weight of water evaporated from 212° by one cubic foot of coal, as contained in the 42d line; and, again, the number in the 41st, divided by the per centage of *combustible matter* of the coal, (obtained by deducting the number in line 13th from 100,) gives the number in line 43. The mode of obtaining the numbers in lines 44 and 45 has already been explained. The entries in lines 46 and 47 are taken from the headings of the tables of experiments. The averages of so many only of the foregoing deductions have been taken as are necessary for forming the synoptical table at the end of each class of coals.

No. 2.

Anthracite from Beaver Meadow Railroad and Coal Company's mine No. 5.

This coal, referred to in the certificate already copied, was received at the same time, and in a similar condition as regards size of pieces, with that just described.

In external characters, it differs to some extent from that sample. The color is jet black; lustre brilliant; fracture variable, uneven, splintery, and often flat-conchoidal. The surfaces of deposition are seldom followed by the fracture of the coal. A slight iridescence is occasionally seen, indicating the presence of a film of sulphuret of iron. The specific gravities of two specimens were found to be, respectively, 1.5529, and 1.5491; and the calculated weight of a cubic foot in the mine is 96.93 pounds, whereas the actual weight of the coal as received was 56.324 pounds per cubic foot, as determined by forty trials of weight in the charge box, requiring 39.77 feet of space to stow one gross ton. From this statement, it appears that the weight in the merchantable condition is to the calculated weight in the mine as 0.5797 to 1. Three boxes reduced to egg size gave respectively 111, 114¾, and 112 pounds per box, or, on an average, 56.29 pounds per cubic foot.

The proportion of moisture obtained in the analysis of the two specimens above referred to was 1.823 and 1.6, which appears to have been above the average; since 28 pounds, exposed in the drying apparatus connected with the boiler, gave in three days a loss of only four ounces, or 0.892 per cent. The trial of 100 grains of the specimen having a specific gravity of 1.5491, yielded of sulphur .062 of a grain.

The total volatile matter, by a mean of two trials, was found to be for the same specimens 3.68 per cent. Four trials by Dr. King on two other specimens of this coal gave a mean of 5.312; so that the mean of four specimens is 4.496. The quantity of earthy matter in this anthracite, as determined by four trials on each specimen, was 2.22 per cent. for the first, and 2.7 for the second.

The character of the ashes obtained in this analysis is that of a light fawn-colored powder, of moderate density, exhibiting no tendency to agglutinate at the temperature employed to produce the incineration, which was that of a muffle kept for some hours at a very bright red heat. In the trials of evaporative power, as exhibited in tables VI, VII, VIII, and IX, which follow, it will be seen that the amount of waste, including both clinker and ashes, with such portions of fine anthracite as escaped separation by the sieve, varied from 5.722 to 7.696 per cent. in the respective trials; and that it was on an average 6.745 per cent. The number of pounds of coal actually consumed was 4,250.5; and the total waste, after deducting the ashes of wood used in raising temperature, was 283.043 pounds, or 6.659 per cent. of the whole. The total clinker was 26.5 pounds = 0.6224 per cent. of the coal.

The actual mean proportion of earthy ingredients and metallic oxides in this sample was found to be 5.149 per cent.

Admitting the six trials for volatile matter to furnish a fair average of that material, viz: 4.496 per cent., and this determination on the large scale to give the true amount of earthy ingredients, we shall have for the *fixed carbon* 90.355 per cent.; whereas the analysis of the two hand specimens gave—

Volatile matter - - - - -	3.68
Earthy matter - - - - -	2.46
Fixed carbon - - - - -	93.86
	100.

The ashes are of a dark gray color, and weigh 51.4 pounds per cubic foot.

The clinker is mostly in small fragments—partly dark iron gray, partly yellowish white. The lighter colored portions are porous and friable, darker portions fused; none very compact. Weight per cubic foot, by experiment, 35 pounds.

The material swept from the flues after four days' burning of this anthracite was 7 pounds, weighing at the rate of 26.97 pounds per cubic foot; showing a greater density than that of any other sample of soot and dust obtained during this research. As the carbonaceous matter was wholly derived from the wood, it might be expected that the remaining material in the flues should be found approximating the weight of the earthy matters of the anthracite. Such will, in general, be found to be the case; and the difference in this respect between coals of this character, and those highly bituminous coals which send forth a copious volume of black smoke, will be sufficiently marked. The times required for bringing the boiler into steady action, after the charging with this coal had been commenced, were as follows:

First trial - - - - - -	2.00 hours.
Second trial - - - - -	3.50 "
Third trial - - - - -	1.416 "
Fourth trial - - - - -	2.75 "
Mean - - - - -	2.416 "

This indicates a greater facility of ignition than was found in the preceding sample; and the relation between the two is expressed by the numbers 2.416 and 3.866.

The quantities of anthracite withdrawn and separated after the several trials, were 89, 42.75, 66, and 47.5 pounds, or an average of 61.31 pounds; while for the preceding sample the average is 112⅜ pounds.

The general principle, that the slowness in bringing the boiler to steady action, and the amount of unburned anthracite left on the grate, are alike indicative of the difficulty of commencing and sustaining the ignition of the anthracites, is rendered at least probable by the approximate relation between the above numbers. For 3.866 : 2.416 : : 112.375 : 70.25. The last number is the *calculated* amount of unburnt anthracite in the sample now under consideration; whereas experiment gives 61.31.

In submitting specimens of both this and the preceding sample to complete ignition, either in a platinum crucible or an iron retort, the form of the fragments remained unaltered. A combustible gas, which burned with a light blue flame, accompanied in some cases with minute scintillations of a brighter light.

TABLE VI.—BEAVER MEADOW

First trial—upper damper 10 inches open; air plates closed;

Date.	Hour.	Temperatures of the							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m.													
	A. M.													
July 6	5.20	69	60	124	200	77	200	-	30.12	0.357	7.00	0.15	-	108.50
	6.35	71	62	116	232	78	224	-	30.14	0.523	5.34	0.17	-	112.50
	7.00	73	62	120	232	78	226	-	30.14	0.523	5.34	0.20	-	-
	8.00	74	61	136	244	78	228	-	30.16	0.523	5.34	0.18	248	117.25
	8.30	76	61	144	250	78	228	-	30.17	0 529	5.28	0.18	572	110.25
	9.00	75	59	162	258	78	229	78	30.17	0.535	5.22	0.22	746	107.75
	9.30	76	58	174	268	78	228	79	30.17	0.539	5.18	0.23	1130	-
	10.10	76	60	198	280	78	228	80	30.16	0.553	5.04	0.31	1810	104.50
	10.40	79	61	220	290	78	230	80	30.18	0.553	5.04	0.31	2240	-
	11.00	80	61	234	295	78	230	80	30.18	0 553	5.04	0.31	2680	113.75
	11.40	80	60	280	285	78	230	80	30.17	0.556	5.02	0.31	3055	-
	P. M.													
	0.15	80	61	300	280	80	230	80	30.17	0.547	5.10	0.30	3625	117.50
	0.55	82	65	330	262	80	229	79	30.16	0.535	5.22	0.30	4480	105.75
	2.00	84	65	384	258	82	228	80	30.15	0.530	5.28	0.30	5380	108.75
	2 30	85	65	376	284	82	230	80	30.14	0 537	5.20	0.30	5783	108.75
	3.00	85	65	382	294	82	230	80	30.14	0.551	5.06	0.32	6118	-
	3.30	85	65	378	290	82	230	81	30.14	0.549	5.08	0.32	6626	-
	4.00	86	67	383	270	82	230	81	30.12	0.541	5.16	0.31	7108	-
	4.45	87	67	388	275	82	230	81	30.12	0.548	5.10	0.31	7673	-
	5.20	85	64	376	274	84	229	81	30.12	0.525	5.32	0.28	8215	-
	5.35	85	65	375	265	84	227	81	30.12	0.527	5.30	0.24	9098	-
	A. M.													
July 7	5.25	73	67	220	190	81	221	73	30.10	0.464	5.92	0.10	9108	-
	6.15	72	68	218	180	81	205	72	30.11	0.356	7.00	0.12	10518	-

Period of steady action this day, from 9 a. m. to 3 p. m. = 6 hours; coal supplied to grate, 659 lbs.; water to boiler, 5,237.83 lbs.; water to 1 of coal, 7.948.

ANTHRACITE, FROM SLOPE No. 5.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 68 feet.
h. m.					
5.00	53.7	56	0	-	First charge thrown behind wood on grate; water at normal level; commenced firing.
6.35	56.2	45	+ 8	-	Steam at equilibrium.
-	55.1	47	6	-	Steam blowing off; water in boiler 0.2 inch above normal level.
7.15	52.5	62	16	0.657	The third charge consists of one large, and the rest small lumps.
8.00	51.3	68	22	1.717	
8.35	46.9	86	29	0.922	Wind NE., brisk, clear.
-	44.5	98	40	2.024	A charge of this coal reduced to egg size weighed 111 lbs.
10.10	49.2	122	52	2.649	
-	49.6	141	60	2.278	Commenced filling tank at 11*h.* 40*m.* a. m., concluded at m.
11.00	49.0	154	65	3.497	
-	46.6	200	55	1.490	A second charge of this coal reduced to egg size weighed 114½ lbs.
0.00	49.9	220	50	2.841	
0.30	56.1	248	33	3.079	
1.40	55.2	300	30	2.396	Filled tank at 1*h.* 50*m.* p. m.
2.35	54.7	291	54	2.135	
-	54.7	297	64	1.776	Wind NW., clear.
-	54.7	293	60	2.691	
-	58.1	302	40	2.553	Contents of ash pit thrown on grate at 3*h.* 55*m.* p. m.
-	57.7	301	45	1.996	
-	52.7	291	45	2.461	Filled tank.
-	54.7	290	38	-	Water in boiler left at 2.1 inches above normal level; damper reduced to 5 inches.
-	64.0	147	—31	-	Water in boiler found at 2.9 inches below normal level.
-	66.0	146	—25	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	9.75
Ashes	46.00
Ashes from behind bridge	11.55
Total ashes and clinker	67.30
Deduct wood ashes	0.461
Total waste from coal	66.839
Coke	47.25

TABLE VII.—BEAVER MEADOW

Second trial—upper damper 5 inches open ; air

Date.	Hour.	TEMPERATURES OF THE: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
July 7	6.15	72	68	218	180	81	205	72	30.11	0.356	7.00	0.12	-	108.75
	7.15	73	67	204	230	81	225	72	30.10	0.515	5.42	0.18	-	117.00
	7.30	74	68	200	244	80	226	72	30.09	0.525	5.32	0.20	-	116.75
	8.00	74	67	198	244	81	227	73	30.09	0.523	5.34	0.20	170	-
	8.30	75	68	196	248	81	227	74	30.07	0.525	5.32	0.20	328	-
	9.00	76	70	200	250	81	227	76	30.07	0.527	5.30	0.25	490	113.50
	9.30	78	70	204	254	80	228	77	30.07	0.533	5.24	0.26	580	-
	10.10	79	71	220	250	80	228	79	30.06	0.540	5.17	0.26	902	-
	10.30	80	71	226	250	78	228	80	30.05	0.531	5.26	0.23	1147	-
	11.00	82	72	236	244	78	228	80	30.04	0.531	5.26	0.22	1399	116.00
	11.30	83	73	246	240	78	228	81	30.04	0.531	5.26	0.21	1567	-
	P. M. 0.00	84	74	258	244	78	227	82	30.02	0.527	5.30	0.21	1907	111.50
	0.30	85	74	264	256	78	228	83	30.00	0.537	5.20	0.26	2162	-
	1.00	87	75	270	264	78	228	84	29.99	0.537	5.20	0.26	2665	-
	1.30	88	75	278	260	78	229	85	29.99	0.540	5.17	0.30	3005	111.25
	2.00	88	74	284	250	78	229	85	29.95	0.530	5.27	0.25	3434	-
	2.30	89	75	300	272	78	229	86	29.95	0.548	5.10	0.28	3774	105.75
	3.00	89	75	308	270	78	229	87	29.94	0.535	5.22	0.27	4097	-
	3.30	91	76	316	268	80	229	88	29.93	0.537	5.20	0.26	4587	-
	4.15	91	76	328	260	80	229	88	29.92	0.537	5.20	0.27	5247	109.00
	4.50	92	76	334	254	85	228	89	29.91	0.537	5.20	0.27	5579	-
	5.30	91	77	342	250	85	228	89	29.90	0.523	5.34	0.26	6252	-
	6.00	91	77	354	250	85	227	89	29.90	0.531	5.26	0.25	6419	125.00
	6.30	91	77	350	250	85	228	89	29.90	0.531	5.26	0.24	6837	-
	6.43	90	78	360	235	85	227	88	29.91	0.533	5.24	0.19	7667	-
	A. M.													
July 8	4.30	78	66	256	220	84	226	-	29.96	0.506	5.50	0.13	7667	-
	5.34	76	66	254	200	84	212	77	29.92	0.353	7.02	0.13	9582	-

Period of steady action, from 10*h*. 45*m*. a. m. to 4*h*. p. m.—5*h*. 15*m*.; coal supplied to grate, 437.5 lbs.; water to boiler, 3,754 lbs.

ANTHRACITE, FROM SLOPE No. 6.

plates closed, and steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 63 feet.
A. M.					
6.15	66.0	146	—25	-	Water brought to 0.05 inch above normal level; 1st charge thrown behind wood on grate.
7.15	64.0	121	+ 5	-	Wood consumed, 119 lbs.; steam at equilibrium; wind S., brisk; sun obscured.
7.30	65.1	126	18	-	Steam blowing off.
-	63.4	124	17	0.901	
-	64.6	121	21	0.837	
9.00	66.5	122	23	0.858	
-	66.5	126	26	0.477	Wind SW., brisk.
-	67.6	141	22	1.279	Filled tank.
-	67.2	146	22	1.947	
10.45	68.1	154	16	1.335	
-	69.2	163	12	0.890	
11.55	70.4	174	17	1.801	
-	70.0	179	28	1.351	Wind S., clear.
-	70.9	183	36	2.665	At 1*h*. 15*m*. p. m., drew in 15 minutes 105 cubic inches of gases, which gave 0.90 gr. of water, 5.96 grains of carb. acid, and 14.566 cubic inches of oxygen gas.
1.30	70.6	190	31	1.821	
-	69.1	196	21	2.273	
2.30	70.3	211	43	1.801	
-	70.3	219	41	1.711	
-	71.2	225	39	2.596	
4.00	71.2	237	31	2.331	Filled tank at 4*h*. 30*m*. p. m.
-	70.9	242	26	1.507	Dew point, by observation, 72°; by calculation, at same place, 71°.5.
-	72.7	251	22	2.674	Wind SW., brisk.
5.45	72.7	262	23	0.885	
-	72.7	259	22	2.215	Contents of ash pit thrown on grate.
-	74.4	270	8	-	Water in boiler left at 2.4 inches above normal level.
-	59.8	178	— 6	-	Water found more than 3.5 inches below normal level.
-	60.8	178	—12	-	Water in boiler adjusted; fire on grate.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	7.25
Ashes - - - - - - - - - - -	59.75
Ashes from behind bridge - - - - - - - -	10.56
	77.56
Deduct wood ashes - - - - - - - - - -	.365
Total waste from coal - - - - - - - -	77.195
Coke - - - - - - - - - - -	66.

TABLE VIII.—BEAVER MEADOW

Third trial—upper damper 10 inches open; air plates open five

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.
	h. m.												
	A. M.												
July 8	6.00	75	66	230	195	84	208	77	29.99	0.350	7.05	0.14	–
	6.30	79	68	234	250	84	230	78	30.02	0.540	5.16	0.20	–
	7.30	78	67.5	228	268	82	232	78	30.03	0.580	5.27	0.25	407
	8.00	79	68	230	285	82	232	79	30.04	0.543	5.14	0.26	407
	8.30	79	66	248	262	79	230	78	30.04	0.525	5.32	0.26	779
	9.00	80	68	264	255	79	231	80	30.03	0.527	5.30	0.26	1035
	9.45	83	67	278	268	79	231	81	30.03	0.535	5.22	0.26	1375
	10.15	84	68	284	262	79	230	81	30.03	0.527	5.30	0.28	1626
	11.00	83	66	284	262	80	232	82	30.03	0.531	5.26	0.26	1879
	11.40	84	68	296	292	80	232	82	30.03	0.545	5.12	0.30	2217
	P. M.												
	0.10	85	66	298	312	80	233	83	30.03	0.545	5.12	0.31	2805
	0.40	86	68	310	302	79	232	83	30.01	0.553	5.04	0.34	3230
	1.00	86	65	316	286	80	232	83	30.01	0.545	5.12	0.33	3475
	2.00	86	68	368	308	80	232	83	30.01	0.555	5.02	0.34	4472
	2.40	88	68	386	305	80	233	84	30.00	0.552	5.05	0 36	5250
	3.20	88	70	400	290	86	232	85	30.00	0.524	5.33	0.32	5890
	3.50	89	69	418	284	86	232	85	29.99	0.535	5.22	0.30	6306
	4.20	80	73	412	268	86	232	86	29.98	0.543	5.14	0.32	6621
	4.50	89	70	402	–	86	233	85	29.98	0.551	5.06	–	7046
	5.20	89	71	410	298	86	233	85	29.97	0.550	5.08	0.33	7801
	5.50	83	76	424	265	86	233	85	29.96	0.578	4.80	0.20	7931
	6.00	89	71	436	244	86	238	86	29.96	0.606	4.52	0.20	8531
	P. M.												
July 9	3.30	82	71	196	170	84	220	84	29.99	0.419	6.38	0.12	8646
	4.20	82	70.5	195	–	84	205	84	29.96	0.341	7.11	0.11	10975

Period of steady action this day, from 8*h.* 15*m.* a. m. to 5*h.* p. m.=8*h.* 45*m.* Coal supplied to the grate, 779.25 lbs.; water to boiler, 7,234.75 lbs.; hence, water to 1 of coal for the period, 8.409.

ANTHRACITE, FROM SLOPE No. 5.

[illegible] steam thrown into chimney, and small furnace in action.

	[illegible]	Dew point, by calculation.	Gain of temperature [illegible]	[illegible] gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 60 feet.
	h. m.					First charge thrown on back of grate, behind wood.
108.75	6.00	61.3	175	—13	-	Commenced firing; water 0.07 inch above normal level; additional weight on safety valve.
108.75	6.30	62.6	165	+20	-	Water in boiler 0.3 inch above normal level; additional weight removed from safety valve; steam blows off.
115.50	7.20	62.4	160	36	-	Water in boiler 0.9 inch above normal level; five rows of holes opened in air plates.
-	-	62.8	161	63	0.924	Water in boiler at normal level; filled tank at 8h. 15m. a. m.
105.50	8.15	59.4	169	32	1.923	
-	-	62.4	184	24	1.404	Wind N., light; sun shining, but hazy.
116.00	9.45	59.4	195	37	1.201	Placed 28 lbs. of this coal in bucket to dry.
-	-	60.7	200	32	1.225	
-	-	57.5	201	30	0.897	
114.00	11.10	60.7	[illegible]	60	1.343	
104.50	0.10	56.6	213	79	3.115	A charge of this coal broken to egg size weighed 112 lbs.
-	-	59.9	224	70	2.251	
110.50	1.00	54.2	230	54	1.947	
119.75	[illegible]	59.9	[illegible]	76	2.641	
-	-	59.1	299	72	3.091	Filled tank at 3h. p. m.
111.75	3.30	62.2	312	58	2.543	Commenced drawing gases at 4h. 0m.; but the apparatus having become deranged, the drawing was suspended.
-	-	60.5	329	52	[illegible]	
-	-	70.3	332	36	1.351	Floor sprinkled with water; commenced drawing gases at 4h. 38m. p. m.; drew in 12 minutes, 60 cubic inches, which gave 0.37 grain of water, 3.99 grains of carbonic acid, and 8.66 cubic inches of oxygen gas. Filled tank at 5h. 30m. p. m.
-	-	62.2	313	-	2.251	
10[illegible].75	5.00	63.9	321	65	3.000	
-	-	72.6	341	22	[illegible]	Contents of ash pit thrown on grate at 5h. 40m.; air plates closed, and valves double weighted.
-	-	63.9	347	6	-	Water in boiler left at 2.2 inches above normal level; valves unloaded; damper reduced to 5 inches.
-	-	[illegible]	114	—50	-	Water in boiler not visible in tube of water gauge.
-	-	[illegible]	113	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	7.25
Ashes	56.00
Ashes behind bridge	11.60
Total ashes and clinker	74.85
Deduct wood ashes	0.336
Total waste from coal	74.514
Coke	42.75

TABLE IX.—BEAVER MEADOW

Fourth trial—upper damper 5.

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
July 10	5.35	75	71	164	182	82	186	77	29.91	0.346	7.10	0.09	-	103.75
	7.10	78	73.5	164	244	82	226	77.5	29.88	0.510	5.46	0.17	-	116.00
	8.00	79	75	164	260	81	230	78	29.88	0.525	5.32	0.22	150	119.75
	8.30	79.5	74.5	166	246	81	228	79	29.88	0.517	5.40	0.21	379	-
	9.00	80	75	175	248	81	230	80	29.88	0.529	5.28	0.22	552	-
	9.30	81	75	184	248	81	230	80	29.88	0.529	5.28	0.22	866	-
	10.00	82	75	194	248	81	230	81	29.88	0.527	5.30	0.20	1124	114.00
	10.40	83	76	204	254	81	230	82	29.88	0.529	5.28	0.22	1387	-
	11.10	85	74	214	244	81	230	82	29.88	0.524	5.33	0.20	1552	119.75
	11.40	84.5	75	222	244	80	220	83	29.88	0.523	5.34	0.20	1757	-
	P. M. 0.15	85	75	224	246	80	230	84	29.88	0.527	5.30	0.20	1952	-
	0.45	84.5	74.5	220	......	81	230	84	29.88	0.533	5.24	-	2395	-
	1.25	84	76	232	248	81	230	84	29.87	0.523	5.32	0.23	2632	119.00
	2.00	84	76	234	262	81	230	84	29.88	0.532	5.25	0.22	2802	-
	2.30	85	75	242	248	81	229	84	29.87	0.520	5.37	0.21	3142	111.75
	3.20	86	75	254	246	81	230	84	29.85	0.525	5.32	0.21	3397	-
	4.00	87	76	258	242	81	230	85	29.85	0.523	5.34	0.20	3647	-
	4.40	86	76	270	240	81	229	85	29.84	0.518	5.39	0.20	3990	123.00
	5.20	88	76	274	242	81	230	85	29.84	0.523	5.34	0.20	4244	-
	6.00	86.5	78	284	248	82	232	85	29.84	0.535	5.22	0.18	4414	-
	6.10	86	76	288	240	82	229	84.5	29.84	0.494	5.62	0.13	5091	-
July 11	A. M. 6.15	78	74	224	242	82	228	78	29.88	0.516	5.40	0.18	5094	-
	7.45	79	74	213	218	82	227	79	29.91	0.506	5.51	0.15	5094	-
	8.36	79	74	210	214	82	208	79	29.90	0.348	7.08	0.12	7194	-

The period of steady action this day is from 9*h*. 55*m*. a. m. to 4*h*. 35*m*. p. m.—6*h*. 40*m*.; coal supplied to grate in that time, 473.5 lbs.; water to boiler, 2,866 lbs.

ANTHRACITE, FROM SLOPE No. 5.

inches open ; air plates open 5 rows.

		gases.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
					First charge of coal thrown on grate behind wood.
6.35	69.2	80	— 4	-	Water 0.05 inch below normal level; commenced firing.
7.10	71.7	86	+18	-	Water in boiler 0.33 inch above normal level; steam blowing off.
7.45	73.5	85	30	0.477	
-	73.6	86.5	18	1.213	
-	73.2	95	18	0.917	
-	72.8	108	18	1.664	
9.55	72.5	112	18	[illegible]	
-	73.6	121	24	1.046	Filled tank.
11.10	70 0	139	14	0.674	
-	71.7	137.5	16	1.066	Wind SW.; cloudy.
-	71.5	129	16	0.886	Commenced drawing gases at 0h. 33m.; drew in 32 minutes 100 cubic inches, which gave 0.96 grain of water, 3.35 grains of carbonic acid, and 16.39 cubic inches of oxygen gas.
-	70.9	135.5	-	1.616	No observation on the gas entering chimney could be taken while gas was drawn, which causes the blank in that column.
1.00	[illegible]	148	19	[illegible]	
-	[illegible]	150	33	0.[illegible]72	
2.55	71.5	157	[illegible]	[illegible]	
-	71.2	168	16	[illegible]	
-	72.4	171	12	0.993	Commenced drawing gases from *upper flue* at 4h. 24m.; drew in 31 minutes 100 cubic inches, which gave 0.64 grain of water, 2.46 grains carbonic acid, and 19.00 cubic inches oxygen gas.
4.35	[illegible]	184	11	1.369	
-	72.1	166	12	[illegible]	Filled tank at 5h. 45m. p. m.
-	75.2	197.5	16	0.676	Air plates closed, and contents of ash pit thrown on grate.
-	72.7	202	11	-	Water in boiler left at 2 inches above normal level.
-	72.5	146	14	-	Steam still blowing off; fire yet burning on grate; raining.
-	72.1	134	— 9		
-	72.1	131	+ 6	-	Contents of grate and ash pit withdrawn; water in boiler adjusted; ceased raining.

RESIDUA.

	Pounds.
Clinker	2.35
Ashes	81.50
Ashes from behind bridge	2.39
Total ashes and clinker	86.04
Deduct wood ashes	0.646
Total waste from coal	84.495
Coke	80.
Soot (4 burnings)	7.

TABLE X.—DEDUCTIONS

Experiments on Beaver Meadow

	Nature of the data furnished by the respective tables.	1st Trial. (*Table VI.*)	2d Trial. (*Table VII.*)
		July 6.	*July 7.*
1	Total duration of the experiment, in hours	24.917	23.317
2	Duration of steady action, in hours	6.0	5.25
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	11.0	10.0
7	Total weight of coal supplied to grate, in pounds	1215.25	1134.5
8	Pounds of coal actually consumed	1168.0	1068.5
9	Pounds of coal withdrawn and separated after trial	47.25	66.0
10	Mean weight, in pounds, of one cubic foot of coal	55.287	56.723
11	Pounds of coal supplied per hour, during steady action	109.833	88.83
12	Pounds of coal per square foot of grate surface, per hour	7.806	5.922
13	Total waste, ashes and clinker, from 100 pounds of coal	5.782	7.224
14	Pounds of clinker alone, from 100 pounds of coal	0.8896	0.6748
15	Ratio of clinker to the total waste per cent.	14.497	9.340
16	Total pounds of water supplied to the boiler	10518.0	9882.0
17	Mean temperature of water, in degrees Fahrenheit	81°.0	81°.5
18	Pounds of water supplied at end of experiment, to restore level	1410.0	2215.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	181.0	279.0
20	Pounds of water evaporated per hour, during steady action	872.972	715 04
21	Cubic feet of water per hour, during steady action	13.967	11.44
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.312	1.894
23	Pounds of water per sq. ft., by a mean of several observations	2.312	1.870
24	Water evaporated by 1 of coal, from initial temp. (a) final result	8.8501	8.9873
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	7.948	9.083
26	Pounds of fuel evaporating one cubic foot of water	7.0621	6.9543
27	Mean temp. of air entering below ash pit, during steady pressure	81°.92	86°.61
28	Mean temp. of wet bulb thermometer, during steady pressure	63°.08	74°.37
29	Mean temperature of air, on arriving at the grate	310°.15	284°.83
30	Mean temperature of gases, when arriving at the chimney	279°.31	254°.78
31	Mean temperature of steam in the boiler	229°.46	228°.22
32	Mean temperature of attached thermometer	80°.08	84°.5
33	Mean height of barometer, in inches	30.151	29.976
34	Mean number of volumes of air in manometer	5.117	5.228
35	Mean height of mercury in manometer, in atmospheres	.5455	.5342
36	Mean height of water in syphon draught gauge, in inches	.289	.2536
37	Mean temperature of dew point, by calculation	52°.19	70°.09
38	Mean gain of temperature by the air, before reaching grate	228°.23	197°.72
39	Mean difference between steam and escaping gases	46°.8	28°.63
40	Water to 1 of coal, corrected for temperature of water in cistern and boiler	8.8161	8.9528
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern and boiler	9.9460	10.1002
42	Pounds of water, from 212°, to 1 cubic foot of coal	549.40	572.93
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.5496	10.8868
44	Mean pressure, in atmospheres, above a vacuum	1.4434	1 4198
45	Mean pressure, in pounds per square inch, above atmosphere	6.5480	6.1997
46	Condition of the air plates, at the furnace bridge	Closed.	Closed.
47	Inches opening of damper, (U. upper, L. lower)	U. 10	U. 8

FROM TABLES VI, VII, VIII, IX.

anthracite coal, from slope No. 5.

3d Trial. (*Table VIII.*)	4th Trial. (*Table IX.*)	Averages.	Remarks.
July 8.	*July* 10.		
34.383	27.0		
8.75	6.667		
14.07	14.07		
377.5	377.5		
18.75	18.75		
11.0	8.0		
1218.75	927.0		
1176.0	838.0		
42.75	89.0	61.25	It appears that when the damper was drawn 10 inches, the coal left was 45 lbs.; when drawn 5 inches, it was 77.5 lbs.
55.397	57.937	56.324	As the whole forty charges weighed 4495.3 lbs., the mean weight of a cubic foot *thus derived* is 56.194 lbs.
89,057	71.021	88.31	
6.822	5.047	6.274	
6.386	7.696	6.745	
0.6131	0.2661	0.5959	
9.676	3.4576	9.2426	
10975.0	7194.0		
82°.9	81°.4		
2335.0	2100.0		
290.0	269.0		
747.718	429.87	691.4	
10.363	6.877	10.662	
1.981	1.1387	1.8314	
1.986	1.1621		
9.0859	8.2637	8.7967	
8.409	6.0528	7.8732	
6.8788	7.5632	7.1146	
84°.22	84°.83		
68°.14	75°.30		
324°.00	226°.73	286°.	
282°.76	247°.14	266°.	
231°.89	229°.80		
82°.44	83°.13		
30.013	29.869		
5.173	5.312		
.5398	.5257		
.3014	.209	.2632	
61°.89	72°.18		
239°.78	143°.40	202°.032	
50°.86	17°.70	35°.997	
9.0487	8.232	8.7624	
10.1819	9.287	9.8788	
564.05	538.06	556.11	
10.8707	10.0613	10.592	The efficacy of the pound of *combustible matter* on the 4th day's trial, was less than on any of the others. The combustion and evaporation were much slower, the per centage of waste greater, and yet the temperature of the air entering the chimney was but little above that of steam in the boiler. The open air plates may probably, in connexion with the partially drawn damper, be regarded as the cause of this inferiority of useful effect.
1.4017	1.3953	1.4225	
6.2756	5.8384	6.2404	
Open (5 rows) U. 10	Open (5 rows) U. 5		

No. 3.

Anthracite of the "Forest Improvement" Company.

This sample of coal came to hand accompanied by the following certificate from the superintendent of the company, by whom it was sent:

"I certify that the anthracite coal forwarded to the navy yard, Washington, in the casks marked '*Forest Improvement*,' was mined in August last, on the land of the Forest Improvement Company, in the township of Branch, and county of Schuylkill, and State of Pennsylvania, from the vein known as the 'Forest vein.'

"I further certify that the said coal has been promiscuously taken at New York from a cargo delivered to the Jackson ferry, in New York, for consumption, and is a fair sample of all the coal delivered from the Forest vein; that the said Forest vein is uniformly free of slate or other impurities; and that any desired quantity can be delivered for a series of years—Philadelphia being the port of shipment.

"SCHUYLKILL HAVEN, (PA.,) *September* 14, 1842.

"CHARLES DE FOREST,
"*Superintendent Forest Improvement Company.*"

The exterior characters of this anthracite are somewhat different from those of either of the preceding. The main cleats, or partings, are marked by thin lamellæ of white earthy matter, apparently composed of sulphate of lime. These partings, however, are only observable in two positions of the specimens, and but little affect the general color of the coal, which is deep black, with occasional approaches to blue-black, in parts slightly tinged with oxide or sulphuret of iron.

The fracture is uneven, seldom conchoidal, and only occasionally taking place at the surfaces of deposition—revealing, however, when this does occur, moderately abundant deposites of mineralized charcoal in the seams.

The specific gravity of two specimens was found to be 1.4799 and 1.4741—the mean of which would give the calculated weight of a cubic foot of coal *in the mine* 92.31 pounds; while thirty-seven trials by measuring and weighing in the charge box gave its weight, in the condition of lumps as received, 53.658 pounds per cubic foot—requiring, of course, 41.74 cubic feet of space for the stowage of one gross ton.

The ratio of the computed to the actual weight of a cubic foot is 1 to 0.5812.

A box of this anthracite broken to the "egg" size was found to weigh 106 pounds, or 53 pounds to the cubic foot; proving that no advantage, in point of stowage, would be derived from reducing it to this state.

Trials on portions of the two specimens above referred to, reduced to powder and dried in the apparatus fig. 1, plate I, gave for moisture 1.162 and 1.213 per cent., respectively; and 28 pounds dried for three days in the apparatus connected with the boiler, showed a loss of 8 ounces, or 1.785 per cent.

By exposure to full ignition, the two specimens lost, in addition to the moisture, 3.158 and 2.437 per cent., respectively, giving the total volatile matter 4.32 and 3.65. In two specimens tried by Dr. King, the volatile matter appeared to be 5 and 6.37 per cent. Hence the average from four specimens is 4.835.

The proportion of sulphur obtained from one of the above specimens was scarcely more than a trace, being only .0165 of 1 per cent. The method of trial does not take cognizance of the sulphur which may be

found in the sulphate of lime; nor is this necessary for any purpose of determining the character of the coal, as influenced by the portion of sulphur, or rather of pyrites, which it may contain.

The trials for earthy impurity in the two specimens of this anthracite gave 3.22 for the first, and 2.89 for the second—leaving, after deducting these and the volatile ingredients, 92.46 and 93.46 per cent. of fixed carbon. The complete incineration was, as usual, insured by continuing the process for some hours, and occasionally agitating the residue, to expose every part to the action of the air.

The color of the ashes is a light fawn, with specks of pure white.

In burning, during the four trials of this coal under the steam boiler, 3,810 pounds, there were obtained 262 pounds of *waste*, of which 31.5 pounds, or about 12 per cent., were in the state of clinker; hence it appears that the ashes alone, mixed as usual with fine anthracite, were 6.068, and the clinker 0.826—total, 6.894 per cent. of the coal burned. When the ashes were completely freed from combustible, the residue was but 59.32 per cent. of what it was with the unburnt anthracite remaining; and, when the clinker was also completely reincinerated, it lost 1.455 per cent. Hence the waste withdrawn was made up of ashes 3.6, clinker 0.814, and carbon 2.48—total, 6.894 per cent.

The ashes, as they came from the furnace, weighed 44.03 pounds per cubic foot, and the clinker 30.75 pounds; the former being of a dark gray color, and the latter varying from dark iron-gray to a nearly white color. Many fragments are portions of slate in their original forms, very friable, and having little tendency to cohere. The vitrification is so imperfect as to cause but little clogging of the grate in any of the trials. The total amount of soot and dust withdrawn from the flues after four trials of this coal, was only 3 pounds, weighing at the rate of 17.94 pounds per cubic foot. Of this, 52.63 per cent. was incombustible earthy matter. The trivial influence, or rather absence of all effect of this quantity of dust in impeding the progress of heat through the metal of the boiler, is apparent in the close conformity observable between the first and fourth trials, in regard to the amount of water evaporated by one of combustible matter—both trials being conducted with the same damper drawn to the same extent, and with the air plate at the bridge *closed*. The first gave 11.17, and the fourth 11.20 pounds of water to 1 of combustible matter from 212°.

The reductive power of this coal, applied to the oxide of lead, is expressed by 32.022; 20 grains of the coal having produced 640.44 grains of metallic lead. The ignition of this coal appears to take place with considerable difficulty; having required, on an average, 3.32 hours, from the time the first charge was laid upon the grate, to bring the boiler to the condition of "steady action." The weight of anthracite left unburnt on the grate was 40.18. It should be, however, borne in mind, that no charge of anthracite was laid upon the grate previous to the commencement of firing with wood, as had been done in some trials of the samples already described.

For domestic purposes, this anthracite is well adapted, both from its high heating power, the small proportion of clinker which it is liable to produce, and from the comparative ease with which the ignition takes place. For smiths' purposes, and for the manufacture of iron, it will present the advantage of a small proportion of earthy matter, and an almost entire freedom from sulphur. A high temperature may probably be found requisite, in order to fuse completely its earthy ingredients.

TABLE XI.—FOREST IMPR

First trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	Temperatures of the							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m. A. M.													
Aug. 4	5.15	71	68	142	150	78	184	73	30.26	0.358	7.02	0.12	-	-
	6.30	73	68	142	246	78	232	-	30.26	0.581	4.76	0.21	-	107.25
	6.45	73	69	146	240	78	236	72.5	30.27	0.590	4.68	0.21	-	107.25
	7.15	74	69	150	248	77	232	73	30.28	0.527	5.30	0.23	230	-
	7.45	76	70	160	258	77	232	74	30.26	0.533	5.24	0.23	455	105.50
	8.15	77	71	174	264	77	232	74	30.26	0.549	5.08	0.30	710	-
	8.45	78	71	186	279	78	232	75	30.26	0.549	5.08	0.30	990	-
	9.15	79	71	205	262	77	232	76	30.26	0.544	5.13	0.26	1560	109.75
	9.45	80	71	217	283	78	232	77	30.27	0.555	5.02	0.31	1988	-
	10.15	80	71	228	284	78	232	78	30.28	0.546	5.11	0.30	2365	106 75
	10.45	82	72	249	282	78	232	79	30.27	0.551	5.06	0.31	2850	-
	11.15	82	71	264	278	77	232	79	30.28	0.543	5.14	0.28	3413	101.50
	P. M.													
	0.00	84	72	286	280	78	231	80	30.28	0.540	5.17	0.28	4177	100.50
	0.30	84	72	302	287	78	231	81	30.28	0.532	5.25	0.26	4592	-
	1.00	83	72	313	283	78	232	81	30.28	0.535	5.22	0.28	5169	110.50
	2.00	87	71	337	288	78	232	81	30.28	0.535	5.22	0.25	6207	102.00
	2.30	86	72	342	282	78	232	81	30.27	0.535	5.22	0.23	6647	-
	3.00	86	71	338	283	78	232	81	30.26	0.535	5.22	0.25	7057	-
	3.30	84	70	340	292	78	232	81	30.27	0.555	5.02	0 32	7471	106.00
	4.00	84	70	342	270	80	231	81	30.27	0.525	5.32	0.21	8178	-
	5.45	81	68	338	255	80	228	79	30.27	0.522	5.35	0.20	9451	-
	A. M.													
Aug. 5	5.40	72	70	194	196	80	214	74	30.22	0.381	6.74	0.13	9460	-
	5.55	72	70	195	194	80	210	74	30.22	0.357	6.98	0.17	9771	-

Period of steady action, from 9*h.* 7*m.* a. m. to 3*h.* 15*m.* p. m. — 6.133 hours, including 11 sets of observations.

OVEMENT ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
h. m.					
-	66.5	71	—34	-	Commenced firing; water at normal level at 200°; morning cloudy, wind NE., light; 2 weights on safety valve.
6.30	65.5	69	+14	-	Commenced charging with coal; wood consumed 212½ lbs.
6.45	67.1	73	4	-	Second weights removed from safety valves; steam escapes
-	66.6	76	16	1.219	rapidly.
7.42	67.3	84	26	1.192	
-	68.4	97	32	1.351	Weighed 28 lbs. of this coal, and placed in kettle for drying.
-	68.0	108	47	1.483	
9.07	67.6	126	30	3.019	Fourth charge in large lumps.
-	67.2	137	50	2.267	
10.15	67.2	148	52	1.997	Fifth charge, lumps.
-	68.1	167	50	2.569	Sun shining dimly; wind E., brisk.
11.05	66.5	182	46	2.983	
0.00	67.3	202	49	2.698	Filled tank at 11*h*. 40*m*. a. m.
-	67.3	218	56	2.199	A charge of this coal reduced to egg size weighed 106 lbs.
1.00	67.7	230	51	3.057	
2.15	64.7	250	56	2.749	
-	66.6	256	50	2.331	
-	65.0	252	51	2.172	
3.15	64.1	256	59	2.193	Filled tank at 3*h*. 35*m*. p. m.
-	64.1	258	49	3.772	Contents of ash pit thrown on grate; damper reduced to 5 inches.
-	62.0	257	27	-	Water in boiler left at 1 inch above normal level.
-	69.1	122	—18	-	Water 0.55 inch below normal level, at temperature 214°; wind NE., raining.
-	69.1	123	—16	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	10.25
Ashes - - - - - - - - - -	41.75
Ashes behind bridge - - - - - - - - -	1.50
Total ashes and clinker - - - - - - - -	53.50
Deduct wood ashes - - - - - - - - -	0.652
Total waste from coal - - - - - - - - -	52.848
Coke - - - - - - - - - -	22.08

TABLE XII.—FOREST IMPR

Second trial—upper damper 8 inches open; air plates open;

Date.	Hour.	Temperatures of the							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m A. M.													
Aug. 5	6.00	72	70	195	194	80	210	-	30.22	0.357	6.98	0.17	-	-
	7.00	72.5	70.5	183	232	80	226	-	30.21	0.535	5.30	0.18	-	97.25
	7.18	74	71	180	242	80	229	-	30.20	0.525	5.30	0.20	-	105.75
	8.00	74	71	175	250	80	226	74	30.20	0.527	5.30	0.20	70	-
	8.30	74	72	178	250	80	228	74	30.20	0.529	5.28	0.20	245	99.50
	9.00	76	73	181	262	80	230	74	30.19	0.537	5.20	0.20	375	-
	9.30	76	74	188	270	80	229	75	30.17	0.543	5.14	0.22	762	-
	10.00	79	76	192	272	80	229	76	30.16	0.537	5.20	0.25	1000	107.00
	10.30	82	77	201	265	80	230	77	30.16	0.527	5.30	0.21	1323	-
	11.00	83	77	208	268	76	232	79	30.16	0.541	5.16	0.23	1520	-
	11.30	84	78	214	270	76	232	80	30.16	0.540	5.17	0.23	1841	96.50
	P. M.													
	0.00	81	77	222	274	76	232	81	30.16	0.547	5.10	0.26	2095	-
	0.30	82	77	228	274	77	232	80	30.16	0.540	5.17	0.28	2383	103.75
	1.00	82	77	235	272	77	232	80	30.16	0.535	5.22	0.23	2633	-
	1.30	83	75.5	235	260	77	232	80	30.16	0.530	5.26	0.25	3053	-
	2.00	82	77	246	285	77	232	80	30.16	0.540	5.16	0.26	3385	106.00
	2.30	84	78	252	290	78	232	80	30.16	0.549	5.08	0.30	3815	-
	3.00	83	77	256	286	78	232	80	30.15	0.543	5.14	0.26	4241	-
	3.30	83	77	265	278	78	232	80	30.14	0.541	5.16	0.26	4645	111.25
	4.00	82	76	273	284	78	232	80	30.15	0.545	5.12	0.30	5058	-
	4.30	81	76	284	288	78	232	79	30.16	0.547	5.10	0.30	5611	118.50
	5.10	80	74	290	302	77	232	77	30.16	0.551	5.06	0.31	6252	-
	5.30	80	74	290	302	78	232	77	30.16	0.539	5.18	0.28	6670	111.00
	6.00	80	74	296	308	78	232	76	30.16	0.545	5.12	0.30	7098	-
	6.30	82	74	296	292	78	230	76	30.17	0.525	5.32	0.22	7574	-
	6.40	81	74	310	254	78	228	77	30.17	0.527	5.30	0.20	7956	-
	A. M.													
Aug. 6	2.30	84	76	178	195	78	207	85	30.12	0.346	7.10	0.12	7962	-
	2.55	84	76.5	176	189	78	202	86	30.11	0.344	7.12	0.12	9370	-

Period of steady action this day, from 10*h*. 25*m*. a. m. to 5*h*. 30*m*. p. m. = 7*h*. 5*m*. Coal supplied to the grate in that time, 647 lbs.; water to boiler, 5,403 lbs.; water to 1 of coal, 8.351.

OVEMENT ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
h. m.					
-	69.1	123	—16	-	Commenced firing; water at 0.1 inch above normal level at 210°.
7.00	69.6	110.5	+ 6	-	Wood consumed, 94½ lbs.; commenced charging with coal; water 0.35 inch above normal level at 226°; steam blows off at 7h. 18m. a. m.
7.18	69.7	106	18		
-	69.7	101	24	0.265	Wind NE., light; raining; air plates opened at 8h. 20m. a. m.
8.25	71.1	104	22	0.927	
-	71.8	105	32	0.689	
-	73.2	112	41	2.050	Floor covered with rain water; wind SE.; rain less.
10.25	75.0	113	43	1.261	Sun coming out; rain has ceased.
-	75.3	119	35	1.711	One large lump in fourth charge.
-	75.0	125	36	1.044	
11.23	76.1	130	38	1.701	Filled tank at 10h. 50m.; wind SW.; clouding up.
-	75.6	141	42	1.346	Raining.
0.28	75.3	146	42	1.521	Wind W.; sixth and seventh charges in lumps.
-	75.3	153	40	1.324	Commenced drawing gases at 1h. 7m.; drew in 16 minutes 80 cubic inches, which gave 0.51 grain of water, 3.35 grains carbonic acid, and 11.552 cubic inches oxygen; temp'ture at bath 80° at 1h. 30m. p.m.; cloudy, wind W.
-	74.3	152	28	2.225	
1.55	75.3	164	53	1.759	
-	76.1	168	58	2.278	Wind NW.; clearing off.
-	75.0	173	54	2.257	
3.05	75.0	182	46	2.140	Eighth charge nearly all fine.
-	73.9	191	52	2.188	Filled tank at 3h. 45m. p. m.; cloudy.
4.10	74.2	203	56	2.929	Heavy mist falling; ninth charge all fine.
-	71.7	210	69	2.282	Filled tank at 5h. 0m. p. m.; cloudy.
5.20	71.7	210	69	3.324	At 6h. 10m. p. m., treated another portion of the gases drawn at 1h. 7m. p. m., with phosphorus, with same result; barometer 30°.18; thermometer 87°; dew point, by observation, 74°.
-	71.7	216	76	2.267	
-	71.0	214	62	2.522	Sun setting clear; contents of ash pit thrown on grate; damper reduced to 4 inches; air plates closed; water in boiler left at 6h. 40m. one inch above normal level.
-	71.4	229	26		
-	73.3	94	—12	-	Water found 3 inches below normal level.
-	74.0	92	—13	-	Water adjusted in boiler.

RESIDUA.

	Pounds.
Clinker	9.75
Ashes	59.75
Ashes behind bridge	1.31
Total waste	70.81
Deduct wood ashes	.29
Total waste from coal	70.52
Coke	29.76

TABLE XIII.—FOREST IMPR

Third trial—upper damper 4 inches open; air

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of charges of coal.
	h. m. A. M.													
Aug. 7	4.45	80	76	150	170	80	184	80	30.11	0.349	7.06	0.13	-	-
	6.07	81.5	77	154	248	80	225	79	30.09	0.527	5.30	0.20	-	104.00
	6.37	81	77	158	226	80	229	80	30.10	0.552	5.05	0.18	-	107.00
	7.00	81	77	157	230	80	232	81	30 10	0.564	4.94	0.17	-	-
	7.30	82	77	160	222	78	226	82	30.10	0.503	5.54	0.20	164	-
	8.00	82.5	77.5	160	210	78	226	82	30.10	0.512	5.45	0.20	-	-
	8.30	84	78	162	222	78	227	83	30.10	0.521	5.36	0.21	-	104.25
	9.00	84	78	165	244	78	227	84	30.11	0.523	5.34	0.21	309	-
	9.30	85	78	167	256	78	229	85	30.11	0.529	5.28	0.23	401	-
	10.00	87	79	169	248	78	228	85	30.11	0.525	5.32	0.25	739	-
	10.30	88	79	189	250	78	229	85	30.11	0.535	5.22	0.34	991	100.25
	11.00	90	80	186	254	79	229	86	30.11	0.524	5.33	0.22	1249	-
	11.30	90	80	198	260	79	230	87	30.11	0.535	5.22	0.23	1419	-
	P. M.													
	0.00	91	80.5	208	252	79	230	87	30.10	0.527	5.30	0.19	1674	104.75
	0.30	94	80	224	248	79	228	88	30.10	0.521	5.36	0.18	2054	-
	1.00	88	78	225	-	79	231	88	30.10	0.542	5.15	0.20	2259	-
	1.30	91.5	79	235	246	79	230	87	30.07	0 530	5.27	0.16	2592	111.00
	2.00	94	80	249	248	80	230	88	30.08	0.537	5.20	0.19	3014	-
	2.30	95	80	253	244	79	230	88	30.08	0.523	5.34	0.18	3334	-
	3.00	93	81	264	238	80	229	89	30.06	0.523	5.34	0.18	3589	118.75
	3.30	92	81	275	250	81	230	89	30.06	0.530	5.27	0.18	3839	-
	4.00	94	81	288	255	81	230	89	30.06	0.535	5.22	0.18	4215	-
	4.30	92	81	296	250	84	230	89	30.05	0.525	5.32	0.18	4530	115.00
	5.00	92	80	316	248	84	230	88	30.05	0.523	5.34	0.17	4783	-
	5.30	90	79	320	259	84	230	87	30.05	0.527	5.30	0.18	5027	101.50
	6.00	96	82	343	249	84	230	87	30.05	0.550	5.07	0.17	5445	-
	6.30	92	82	382	228	84	229	86	30.05	0.533	5.24	0.18	5973	-
	A. M.													
Aug. 8	5.20	80	77	236	214	84	225	81	30 05	0.497	5.58	0.14	5990	-
	6.05	82	77	214	206	84	211	81	30.06	0.348	7.07	0.15	7567	-

Period of steady action, from 10*h*. 10*m*. a. m. to 5*h*. 30*m*. p. m. = 7*h*. 20*m*., embracing 14 sets of observations; coal supplied to grate, 551 lbs.; water to boiler, 4,204 lbs.; water to 1 of coal, during said period, 7.629.

OVEMENT ANTHRACITE.

plates closed; steam thrown out at back valve.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 63 feet.
h. m.					
-	74.6	70	—14	-	Water 0.12 inch below normal level; commenced firing; fire
6.07	74.9	72.5	+23		in small furnace; two weights on safety valves; commenced
6.37	75.6	77	— 3		charging with coal at 6h. 7m.; consumed 183¾ lbs. of wood;
-	75.6	76	— 2		water in boiler, 0.47 inch above normal level; temperature,
-	75.3	78	— 4	0.821	225°; fire kindles slowly; took, at 7h. 0m., the second weights from valves; syphon rose to 0.30; steam began to blow off; at 7h. 30m. filled tank.
-	75.8	77.5	—16	-	A charge of this coal, reduced to egg size, weighs 105 lbs.
8.30	76.1	78	— 5	-	Kindling takes place slowly.
-	76.1	81	+17	0.554	Wind S., light; hazy, sun shining occasionally.
-	75.8	82	27	0.434	Set upper damper to 4 inches at 9h. 35m.; coal igniting more freely.
-	76.6	82	20	1.791	
10.10	76.3	101	21	1.335	
-	77.2	96	25	1.367	
-	77.2	108	30	0.636	Fire in small furnace extinct, and its damper closed, dew point, by observation, 74°.
0.00	77.6	117	22	1.351	Steam all thrown out at back valve.
-	76.1	130	20	2.013	Commenced drawing gases from lower opening at 0h. 42m.;
-	74.9	137	-	1.086	drew in 25 minutes 80 cubic inches, which gave 0.68 grain
1.30	75.3	143.5	16	1.764	water, 4.33 grains carbonic acid, and 8.018 cubic inches
-	76.1	155	18	2.236	of oxygen; temperature at bath 87°; at 0h. 30m. p. m.
-	75.9	158	14	1.695	wind NW.; showery.
3.00	77.8	171	9	1.351	Wind NE., light; clear.
-	78.0	183	20	1.324	Wind S.; dew point, by observation, 76°; by calculation, at same place, 77°.3.
-	77.5	194	25	1.992	Eighth charge shows much earthy matter in partings, technically called "bony coal."
4.15	78.0	204	20	1.669	Filled tank at 4h. 15m. p. m.
-	76.6	224	18	1.340	Cloudy; wind E., light.
5.30	75.8	230	29	1.293	
-	78.4	247	19	2.215	Cont'ts of ash pit thrown on grate; both valves double weighted.
-	79.4	290	— 1	-	Water in boiler left at 1.6 inch above normal level.
-	76.0	156	—11	-	Water found 3.10 inches below normal level.
-	75.3	132	— 5	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	4.00
Ashes - - - - - - - - - - -	71.25
Ashes behind bridge - - - - - - - -	1.26
Total - - - - - - - - - - -	76.51
Deduct wood ashes - - - - - - - -	0.564
Total waste from coal - - - - - - - -	75.946
Coke - - - - - - - - - - -	67.99

TABLE XIV.—FOREST IMPR.

Fourth trial—upper damper 8 inches open ; air plates closed ;

The period of steady action this day is from 10*h*. 17*m*. a. m., when the fourth charge was in, to 3*h*. p. m., when the last charge was in the furnace, =4*h*. 43*m*. ; coal supplied to grate, 462.25 lbs. ; water to boiler, 4,392 lbs.

OVEMENT ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.		Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 131 feet; height of chimney 63 feet.
h. m.					
–	75.3	133	— 5	–	Water brought to 0.1 inch above normal level; commenced firing; wind SW., clear.
6.50	75.0	131	+33	–	Wood consumed, 97¾ lbs.; commenced charging with coal; put second weight on front valve.
7.15	75.9	131.5	2	–	Ash pit closed, and contents thrown on fire; second weight taken from safety valve.
–	74.7	124	15	0.871	Filled tank.
–	74.7	116	18	0.954	
–	75.3	128	32	0.901	
8.50	75.8	132	42	0.874	
–	76.6	133	66	1.743	
–	76.2	140	72	1.356	
10.17	77.2	164	45	3.560	Some portions of the 4th charge show much earthy matter in the partings.
–	75.8	172	58	2.268	
11.30	75.5	181	74	1.938	Some portions of the 6th charge show much earthy matter in the partings.
–	76.9	193	66	2.503	Wind NW., brisk, clear.
0.30	76.6	200	61	2.559	The coal in drying kettle weighs 27 lbs. 6 oz.
–	76.4	203	58	3.454	
–	77.5	209	66	2.824	Filling tank; 7th charge contains some fine coal; 8th charge nearly all fine.
2.00	77.5	204	72	–	Water in boiler 0.5 inch below normal level; filled tank.
–	74.9	219	50	2.053	Wind SE., cloudy; at 2h. SW., cloudy, followed by rain; commenced drawing gases from lower opening at 3h. 40m.; drew in 36 minutes 80 cubic inches, which gave 1 grain of water, 4.06 grains of carbonic acid, and 0.[illegible] cubic inches of oxygen.
3.00	74.9	214	–	2.146	
–	74.7	212	64	2.230	
–	77.5	224	38	1.764	Contents of ash pit thrown on grate at 3h. 40m.
–	73.9	230	32	–	Water brought to 1.4 inch above normal level.
–	68.2	116	—18	–	Water in boiler found 1.7 inch below normal level.
–	68.2	115	—14	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	7.50
Ashes - - - - - - - - - - - -	55.[illegible]
Ashes from behind bridge - - - - - - - -	1.14
Total clinker and ashes - - - - - - - -	63.[illegible]
Deduct wood ashes - - - - - - - - -	0.[illegible]
Total waste from coal - - - - - - - -	63.[illegible]
Soot and dust from flues - - - - - - - -	3.[illegible]
Coke - - - - - - - - - - - -	39.[illegible]

TABLE XV.—DEDUCTIONS

Experiments on Forest Im

	Nature of the data furnished by the respective tables.	1st Trial. (*Table XI.*)	2d Trial. (*Table XII.*)
		Aug. 4.	*Aug.* 5.
1	Total duration of the experiment, in hours	24.667	32.917
2	Duration of steady action, in hours	6.133	7.083
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	10.0	10.0
7	Total weight of coal supplied to grate, in pounds	1057.0	1056.5
8	Pounds of coal actually consumed	1033.98	1026.74
9	Pounds of coal withdrawn and separated after trial	23.02	29.76
10	Mean weight, in pounds, of one cubic foot of coal	52.85	52.825
11	Pounds of coal supplied per hour, during steady action	102.274	91.34
12	Pounds of coal per square foot of grate surface, per hour	7.268	6.492
13	Total waste, ashes and clinker, from 100 pounds of coal	5.111	6.868
14	Pounds of clinker alone, from 100 pounds of coal	0.979	0.9457
15	Ratio of clinker to the total waste, per cent.	19.1493	13.769
16	Total pounds of water supplied to the boiler	9771.0	9370 0
17	Mean temperature of water, in degrees Fahrenheit	78°.3	77°.9
18	Pounds of water supplied at end of experiment, to restore level	311.0	1408.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	40.0	183.0
20	Pounds of water evaporated per hour, during steady action	954.85	762.78
21	Cubic feet of water per hour, during steady action	15.277	12.20
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.5265	2.0206
23	Pounds of water per sq. ft., by a mean of several observations	2.5195	2.002
24	Water evaporated by 1 of coal, from initial temp. (a) final result	9.4112	8.9282
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	9.336	8.3508
26	Pounds of fuel evaporating one cubic foot of water	6.641	7.0003
27	Mean temp. of air entering below ash pit, during steady pressure	81°.87	82°.0
28	Mean temp. of wet bulb thermometer, during steady pressure	71°.20	76°.43
29	Mean temperature of air, on arriving at the grate	262°.73	252°.93
30	Mean temperature of gases, when arriving at the chimney	279°.0	282°.73
31	Mean temperature of steam in the boiler	232°.0	232°.07
32	Mean temperature of attached thermometer	78°.53	79°.27
33	Mean height of barometer, in inches	30.27	30.157
34	Mean number of volumes of air in manometer	5.145	5.147
35	Mean height of mercury in manometer, in atmospheres	.5424	.5422
36	Mean height of water in syphon draught gauge, in inches	.2791	.264
37	Mean temperature of dew point, by calculation	66°.87	74°.41
38	Mean gain of temperature by the air, before reaching grate	180°.86	170°.93
39	Mean difference between steam and escaping gases	51°.81	47°.86
40	Water to 1 of coal, corrected for temperature of water in cistern	9.3788	8.8974
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	10.599	10.0517
42	Pounds of water, from 212°, to 1 cubic foot of coal	560.15	531.15
43	Water, from 212°, to 1 pound of combustible matter of the fuel	11.1699	10.7963
44	Mean pressure, in atmospheres, above a vacuum	1.4328	1.4334
45	Mean pressure, in pounds per square inch, above atmosphere	6.3924	6.4014
46	Condition of the air plates at the furnace bridge	Closed.	Open.
47	Inches opening of damper, (U. upper, L. lower)	U. 8	U. 8

FROM TABLES XI, XII, XIII, XIV.

provement anthracite coal.

3d Trial. (*Table XIII.*)	4th Trial. (*Table XIV.*)	Averages.	Remarks.
Aug. 7.	*Aug.* 8.		
25.333	25.417		
7.333	4.717		
14.07	14.07		
377.5	377.5		
18.75	18.75		
9.0	8.0		
966.5	890.75		
898.51	850.77		
67.99	39.98	40.188	The unburnt coal left when the damper was drawn 8 inches, was, by a mean of 3 trials, 30.92 lbs.; and when the damper was opened but 4 inches, it amounted to 67.99 lbs.
53.694	55.672	53.7602	
75.139	98.002	91.6888	
5.843	6.993	6.524	
8.453	7.449	6.9702	The largest proportion of waste appears on the third trial, when the combustion was most retarded.
0.4418	0.8780	8.1114	
5.2267	11.786	12.4827	The most rapid combustion (on the first trial) will be observed to give by far the highest proportion of clinker; and *vice versa*, as seen on the third trial.
7567.0	7993.0		
81°.2	83°.5		
1587.0	826.0		
200.0	104.0		
573.23	931,15	805.502	
9.171	14.898	12.8865	The mean of the first and fourth trials shows that with the damper drawn 8 inches, and the air plate closed, the evaporation was 15.087 cubic feet per hour; while the third trial, with the damper drawn but 4 inches, and air plate also closed, the evaporation was but 9.171 cubic feet per hour; or; the difference is 39.2 per cent. of the former number.
1.5189	2.466	2.1331	
1.5083	2.459		
8.1991	9.2727	8.9528	
7.629	9.5013	8.7043	
7.6228	6.7402	7,0011	
96°.24	89°.0		
79°.61	79°.0		
225°.21	270°.94	262°.952	
248°.44	289°.0	274°.792	
229°.21	231°.44		
86°.95	85°.87		
30.085	30.057		
5.288	5.232		
.5282	.5337		
.187	.2971	.2568	
76°.57	76°.24		
134°.97	181°.94	167°.175	
20°.46	62°.66	45°.697	
8 1676	9.2347	8.9196	
9.2064	10.3734	10.0576	
494.33	577.51	540.785	
10.0542	11.2083	10.8072	The slow combustion produced by drawing the damper but 4 inches, during the third trial, evidently reduced the useful efficiency of the unit of combustible matter from 11.058 to 10.054, or 9 per cent.
1.4071	1.4193	1.4232	
6.0126	6.1930	6.2498	
Closed.	Closed.		
U. 4	U. 8		

No. 4.

Beach Mountain anthracite, sent by the Delaware Coal Company of Philadelphia.

This sample of coal was accompanied by the following letter from the president of the company, certifying its origin:

"OFFICE OF THE DELAWARE COAL COMPANY,
"*Philadelphia, September* 27, 1842.

"SIR: Enclosed please find a bill of lading, per sloop General Bloomfield, Skinner, for eight hogsheads, containing about three tons of unbroken Peach Mountain red ash anthracite coals, mined by this company below what is called the 'water level,' on one of the seams now worked by it, on a tract of coal land known by the name of Peach Mountain, and belonging to the company, situated about two miles above Pottsville, in Schuylkill county, Pennsylvania.

"I note these facts as being, according to my recollection of an advertisement of the Navy Department, requested to be communicated with any samples of coal which might be sent to the navy yard, for the experiments intended to be made on the different kinds of coals, to test their relative value for the purpose of generating steam, &c., and for which I respectfully tender the eight hogsheads now forwarded by the General Bloomfield. I shall esteem it a favor to have the results of your experiments on all the varieties which have been forwarded under the invitation of the department for trial, and particularly of the Peach Mountain, when you have had them made.

"I am, sir, very respectfully, your obedient servant,
"JOHN WHITE, *President.*

"BEVERLY KENNON, Esq.,
"*Commandant of the Navy Yard, Washington, D. C.*"

The exterior characters of the Peach Mountain anthracite are—a deep jet-black color; an uneven splintery fracture; a lustre varying from dull to shining, according to the direction in which the fracture is made. Like all the other anthracites, it was wholly unaffected by atmospheric influences in a period of eighteen months, during which they were in my charge.

This sample is more easily separated at the surfaces of deposition than most of the white-ash coals, but less so than that of Lyken's valley. It has no exterior indications of impurity, such as discoloration from oxide of iron, or efflorescences of metallic salts. It has certain surfaces polished and minutely striated, appearing as if they had been subjected to friction under intense pressure. This feature is not, however, of so frequent occurrence in this, as in many other samples of anthracite.

Its specific gravity, determined by two specimens, was found to be 1.465 and 1.4632—the mean of which enables us to calculate the weight of a cubic foot of solid coal at 91.505 pounds. But the weighing of 70 charges of 2 cubic feet each in the state of lumps gave 53.7939 pounds per cubic foot, proving that the actual weight in the market is but 0.5878 of the calculated weight in the mine. The same data prove that 41.64 cubic feet of space will be required for the stowage of one gross ton.

In analyzing the two specimens above referred to, the first gave of moisture 1.128, and the second 1.06 per cent.; and of other volatile matter, the first gave 3.272 per cent., and the second 2.56. From these two trials, the total volatile matter is 4.01 per cent.

Another experiment to determine the moisture and volatile matter was made by taking 40 specimens of the coal, (some out of each day's burning,) and from each separating a small fragment; all the pieces being as nearly as possible of the same size. These were then pulverized together, and a quantity of the powder taken for analysis. It yielded of moisture 0.415 per cent., and of other volatile matter 6.55 per cent.—total 6.965.

From 28 pounds of the coal dried in the apparatus attached to the boiler, the moisture expelled was 1.897 per cent.

100 grains of the second specimen above mentioned gave 0.0062 of a grain of sulphur.

The total volatile matter obtained by Dr. King from two specimens of this coal was 5.7 per cent. To ascertain the amount of earthy matter in the two specimens, three trials were made on the first; the mean result of which was 6.62 per cent. of reddish-gray ashes. On the second, four incinerations gave a mean result of 6.487. The perfect incineration was secured by keeping the assays in the muffle at a full red heat for more than twelve hours.

On the powdered coal, from forty different specimens above mentioned was made an experiment to obtain the mean amount of earthy matter, which for 80.3 grains of coal showed 5.58 grains, or 6.948 per cent. of ashes of rather deeper color than those from the two specimens above tried. This differs from the mean of those two 0.395 of 1 per cent.

During the six trials of this anthracite for evaporative power, there were burned 7,371.875 pounds; from which the "total waste" was 511.118 pounds, or 6.933 per cent. Of this amount, a pretty large portion was separated in the state of clinker, varying from 35 to 48 per cent. of the whole. The proportion of clinker in this, as in other coals, will be found greater or less, according to the greater or less rapidity of the combustion, as will be apparent from the following table of trials above referred to:

No. of trial.	Total weight of coal burned, in pounds.	Weight of coal burned per hour, during steady action.	Total waste, exclusive of ashes of wood, in pounds.	Weight of ashes.	Weight of clinker.	Ratio of clinker to total waste.	Per centage of the total waste.	Damper through which gases passed to chimney.	Distance damper was drawn, in inches.
1st	1566.395	103.830	96.922	49.422	47.500	.4911	6.187	Upper	8
2d	1075.825	102.384	75.240	41.145	34.095	.4531	6.993	Upper	8
3d	1089.078	89.783	81.858	45.508	36.350	.4568	7.516	Upper	8
4th	939.629	77.928	67.340	43.788	23.552	.3497	7.166	Upper	4
5th	1343.977	91.440	96.731	51.298	44.433	.4593	7.197	Lower	4
6th	1356.976	99.730	93.027	53.572	39.445	.4240	6.855	Upper	8

From the above, it will be perceived that, when the coal was burned at the rate of about 104 pounds per hour, the clinker was 49 per cent. of the total waste; and when at 78 pounds per hour, on a grate of the same size, only 35 per cent.

The total amount of ashes, it will be seen from column fifth, was 284.733 pounds; of which a trial by reincineration proved that 22.01 per cent., or 62.67 pounds, was combustible—leaving only 222.063 pounds of earthy matter. The clinker lost nothing by reincineration, but gained a small per centage by peroxidizing some portions of the magnetic oxide of iron found in the interior of its masses. Hence, the true proportion of earthy matter in this coal, exclusive of the dust which passed into the flues, is [illegible] = 6.083 per cent.; and including that dust, it is 6.1253 per cent. This shows that the analysis of forty specimens gave a residue 0.823 per cent. greater than the combustion of three tons of the coal—a result which may be accounted for by the fact that some dust is lost in the combustion on the grate, which does not happen in the muffle; and that, in becoming fused and vitrified, the hydrated earths lose water, becoming anhydrous silicates. This last circumstance is indicated in the table above given, in which it will be perceived that the three trials which yielded the least proportions of waste, (Nos. 1, 2, and 6,) are those in which the coal was burned most rapidly, and in which the proportion of clinker was also higher than that in the three remaining trials.

The clinker was taken from the grate in large fragments. It was found necessary occasionally to withdraw it during the progress of the experiments, in order to maintain the activity of the fire and the uniform action of the boiler. Its color is dark reddish brown without, and nearly black within. It is thoroughly fused and completely agglutinated into plates. The portions of white slaty and unfused matter adhering to it are much less frequent than in several other samples of clinker which have come under observation. Its weight per cubic foot was found to be 45.12 pounds, while that of the ashes was 58.09 pounds. 6 pounds of dust were found in the flues after the trials of this anthracite, which weighed at the rate of 22.4 pounds per cubic foot, and proved on reincineration to contain 51.75 per cent. of incombustible matter.

It appears from all the above data that the constitution of this anthracite may be taken as follows:

Volatile matter, (from 40 specimens) - - -	6.965
Earthy matter, (from the same) - - -	6.948
Fixed carbon - - - - - - -	86.087
Total - - - - - -	100.

Its ignition is effected with difficulty—having required, on an average, 3.537 hours at each trial to bring the boiler up to its uniform rate of action. When once ignited, however, the combustion is continued until the greater part of the contents of the grate have undergone incineration. The mean amount of unburnt anthracite withdrawn was only 26.646 pounds; which is only about four-fifths as much as was left of the Lehigh anthracite, one-half as much as of the Lackawanna coal, less than one-half as much as of the Beaver Meadow mine No. 5, and less than one-fourth as much as was withdrawn after using Beaver Meadow No. 3.

It appears that there were left in the waste—

	Per cent. of carbon.
Of Peach Mountain anthracite - - - -	1.520
Of Forest Improvement - - - - -	2.480
Of Beaver Meadow No. 5. - - - -	2.710
Of Lehigh - - - - - -	1.764
Of Lackawanna - - - - - -	2.675
Of Beaver Meadow No. 3. - - - -	4.800
Of Lyken's valley - - - - -	2.898

The manner in which this coal acts upon the grate, and the readiness with which its cinder agglutinates itself to bricks and other substances of an earthy nature, will constitute some objection to its use in generating steam.

For use in parlor grates, where a slower combustion is maintained, it will be found to sustain a high character. The synoptical table shows that, in evaporative power, it stands at the head of the anthracite class.

As there was a full sample of this coal, several variations in the mode of conducting its combustion were applied. It will also be observed that ample time was taken to give the fuel an opportunity of showing its power, the first trial having been commenced at 40 minutes past midnight, and extended to 7 o'clock in the evening, and other experiments protracted through many hours of steady action.

TABLE XVI.—PEACH

First trial—upper damper 8 inches open; air plates closed;

The period of steady action to-day is from 8*h*. 15*m*. a. m. to 6*h*. 20*m*. p. m.—10*h*. 5*m*., during which 21 sets of observations occur. Coal supplied to grate, 1,047 lbs.; water to boiler, 9,236 lbs.

MOUNTAIN ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
h. m.					
-	68.6	81	—37	-	Water 0.17 inch below normal level; commenced firing; safety valves double weighted.
-	69.2	76	— 2		
3.10	69.2	77	— 4	-	Wood consumed, 188¼ lbs.; commenced charging with coal; water 0.46 inch above normal level.
3.30	69.6	78	— 8	-	Removed additional weights from safety valves at 3*h.* 45*m.*; steam then blows off.
4.20	69.6	83.5	—10	0.722	Ash pit closed, and its contents thrown on grate.
-	68.2	86	+ 4	-	Steam a little above equilibrium.
-	69.1	90	10	0.331	Steam blows off freely; morning cloudy; wind NE., light.
-	69.1	92	24	0.911	Fire getting into lively action.
-	67.5	93	37	1.155	
6.45	68.2	104	53	1.785	Put 28 lbs. of this coal in drying apparatus.
-	68.2	124	57	1.499	Put add'l weight on safety valve (front) to prevent foaming.
-	68.2	138	53	1.351	Normal level temporarily adjusted at 1 inch below what it has heretofore been, to increase steam chamber.
8.15	68.9	150	60	1.934	
-	68.4	170	63	3.179	
9.05	69.5	196	51	2.119	Raining lightly.
-	69.5	210	57	2.437	
10.15	69.5	226	58	2.395	A charge of this coal reduced to egg size weighed 104.5 lbs.
-	69.5	232	58	2.066	Water in boiler about 0.3 inch below level; filling tank concluded at 11*h.* 8*m.*
11.06	70.3	254	49	3.799	
11.55	70.7	263	55	2.241	
-	71.7	272	56	2.622	Commenced drawing gases from lower flue at 0*h.* 36*m.* p. m.; drew in 24 minutes 80 cubic inches, which gave 0.67 grain water, 4.85 grains carbonic acid, and 10.76 cubic inches oxygen; lower damper open.
-	71.0	263	-	1.642	
1.15	71.0	272	50	3.391	
2.10	71.0	282	50	2.073	
-	70.4	286	51	2.628	
-	71.0	288	59	3.723	Cloudy, with occasional rain; wind NE.
3.10	72.6	301	54	2.520	Filled tank at 3*h.* 10*m.* p. m.; raining.
4.00	73.3	308	51	2.670	
-	73.3	320	42	1.685	
5.00	73.8	317	46	3.126	Small additional weights removed from front valve.
-	72.2	315	48	1.967	Filled tank at 5*h.* 20*m.*; clearing up; sun shining.
-	72.2	315	46	2.077	
5.30	73.3	319	40	1.375	Contents of ash pit thrown on grate.
-	73.3	326	32	-	Water 0.6 inch above *true* normal level; both valves double weighted.
-	73.0	313	32	-	Water left at 1.6 inch above true normal level; double weights removed.
-	67.3	170	—16	-	Water entirely below the scale on gauge.
-	69.7	163.5	— 9	-	Water in boiler adjusted; fires in small furnace.

RESIDUA.

Clinker	Lbs. 47.0	Deduct wood ashes	Lbs. [illegible]
Ashes	43.5	Total waste from coal	[illegible]
Ashes, &c., behind bridge	7.0	Coke	[illegible]
Total clinker and ashes	97.5		

TABLE XVII.—PEACH

Second trial—upper damper 8 *inches open; air plates closed;*

Date.	Hour.	Temperatures of the open air entering below ash plt.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
Aug. 11	5.55	79.5	72.5	243	200	76	209	78	30.03	0.352	7.03	0.20	-	114.00
	7.00	79	72	212	252	76	228	75	30.03	0.525	5.32	0.18	-	105.75
	7.30	78	71	223	260	74	238	75	30.04	0.610	4.48	0.21	-	107.75
	8.00	80	71	218	278	74	232	76	30.03	0.542	5.15	0.30	-	-
	8.30	79	71	224	293	74	232	77	30.05	0.545	5.12	0.33	268	-
	9.00	80	72	240	303	74	232	78	30.04	0.558	5.04	0.28	436	106.00
	9.30	80	71	262	302	74	232	79	30.04	0.540	5.17	0.27	750	-
	10.00	82	72	292	302	71	233	79	30.04	0.553	5.04	0.28	1510	114.50
	10.30	82	73	306	300	74	232	80	30.04	0.543	5.14	0.26	2172	-
	11.00	83	74	326	304	74	232	80	30.01	0.543	5.14	0.29	2755	-
	11.30	85	75	334	308	74	232	80	30.01	0.543	5.14	0.28	3250	104.50
	P. M.													
	0.00	86	75	342	306	74	232	80	30.05	0.549	5.08	0.29	3743	-
	0.30	87	75	355	301	76	232	81	30.05	0.537	5.20	0.26	4316	106.25
	1.00	88	76	361	-	76	232	81	30.04	0.547	5.10	0.30	4908	-
	1.30	89	76	364	296	77	232	82	30.05	0.533	5.24	0.29	5648	113.00
	2.00	90	76	372	295	77	232	83	30.04	0,529	5.28	0.29	6083	114.00
	2.30	90	77	371	303	77	232	83	30.04	0.528	5.29	0.29	6508	-
	3.00	91	77	376	302	77	232	84	30.04	0.523	5.34	0.30	7164	-
	3.30	91	77	378	294	78	231	84	30.03	0.534	5.23	0.28	7523	113.25
	4.00	91	77	380	286	78	232	84	30.03	0.534	5.23	0.26	8048	-
	4.30	91	77	384	280	82	230	84	30.03	0.519	5.38	0.24	8368	-
	5.00	89	75	372	284	83	230	83	30.04	0.527	5.30	0.26	9625	-
	A. M.													
Aug. 12	3.00	70	68	234	210	82	222	74	30.08	0.441	6.14	0.15	9638	-
	4.00	74	69	230	206	82	215	74	30.08	0.390	6.66	0.15	10163	-

The period of steady action is computed from 9*h*. a. m. to 3*h*. 30*m*. p. m.—6*h*. 30*m*.; coal supplied to the grate, 665.5 lbs.; water to boiler, 7,087 lbs.

MOUNTAIN ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 63 feet.
h. m.					First charge thrown on grate behind wood.
5.55	69.7	163.5	—9	-	Water brought to 0.1 inch above normal level; commenced firing; wind NW., light; clear.
7.00	69.2	133	+24	-	Wood consumed, 93 lbs.; steam at equilibrium.
7.30	68.0	145	22	-	Filled tank; took second weights from safety valves; steam blows off.
-	67.2	188	46	-	Level temporarily adjusted at 1 inch below normal level, to increase steam chamber.
-	67.6	145	61	1.419	Steam allowed to blow off from both valves.
9.00	68.8	160	71	0.890	Additional small weights on front safety valve, to prevent priming.
-	67.2	182	70	1.664	Small additional weight on safety valve impedes the escape of steam into chimney.
9.35	68.1	210	69	4.026	
-	69.6	224	68	3.507	
-	70.7	243	72	3.089	
11.10	71.5	249	76	2.622	
-	71.2	256	74	2.612	Filled tank at 0*h.* 10*m.* p. m.
0.10	70.9	268	69	3.036	Commenced drawing gases from lower flue at 0*h.* 46*m.* p. m.; drew in 21 minutes 80 cubic inches, which gave 0.66 grain water; 5 62 grains of carbonic acid, and 8.245 cubic inches of oxygen. Temperature at bath 84°.
-	72.1	273	-	3 136	
1.07	71.8	275	64	3.921	
2.00	71.5	282	63	2.305	
-	73.0	281	71	2 252	
-	72.7	285	70	3.475	
3.30	72.7	287	63	1.902	
-	72.7	289	54	2.781	Filled tank at 4*h.* 15*m.* p. m.
-	72.7	293	50	1.695	Contents of ash pit thrown on grate.
-	70.3	283	54	-	Water in boiler left at 1.8 inch above normal level.
-	67.0	161	—12	-	Water 1 inch below normal level; no fire on grate.
-	66.6	156	—9	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	33.75
Clinker from behind bridge	0.345
Ashes	37.00
Ashes from behind bridge	4.43
	75.525
Deduct wood ashes	0.285
Total waste from coal	75.240
Coke	23.175

TABLE XVIII.—PEACH

Third trial—upper damper 8 *inches open ; air plates open ;*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 12	4.00	74	69	230	206	82	215	74	30.08	0.390	6.66	0.15	-	124.25
	4.45	72	68.5	220	260	82	231	73	30.08	0.558	5.00	0.20	-	105.75
	5.15	70	68	212	258	82	232	73	30.08	0.526	5.30	0.23	-	-
	5.45	72	69	211	258	82	230	73	30.08	0.526	5.30	0.23	-	-
	6.15	73	69	211	268	82	230	74	30.08	0.533	5.24	0.23	-	-
	6.45	77	71	212	287	81	232	75	30.08	0.543	5.14	0.28	267	101.50
	7.30	78	71	226	306	81	232	75	30.09	0.548	5.09	0.26	820	109.50
	8.00	80	72	227	301	81	232	75	30.09	0.549	5.08	0.25	1135	-
	8.30	82	73	254	296	81	232	76	30.10	0.543	5.14	0.26	1577	-
	9.05	84	74	268	292	77	231	78	30.09	0.541	5.16	0.28	2135	109.25
	9.30	85	74	274	305	77	232	79	30.09	0.547	5.10	0.27	2465	-
	10.00	86	75	282	308	77	232	80	30.09	0.558	5.00	0.28	2710	118.25
	10.30	86	76	290	302	77	232	81	30.09	0.551	5.06	0.27	3215	-
	11.00	88	76	300	302	77	232	82	30.10	0.558	5.00	0.27	3787	-
	11.30	89	77	310	304	78	233	83	30.10	0.552	5.05	0.28	4289	112.25
	P. M. 0.00	90	76	325	298	78	232	83	30.10	0.550	5.07	0.28	4711	110.25
	0.30	90	75	336	-	77	232	84	30.09	0.552	5.05	0.23	5029	-
	1.10	93	78	344	295	77	232	84	30.10	0.547	5.10	0.24	5572	111.00
	1.30	92	77	344	302	78	232	84	30.10	0.553	5.04	0.26	5807	-
	2.00	94	78	341	298	78	232	84	30.08	0.539	5.18	0.27	6137	-
	2.30	95	80	343	296	78	233	84	30.08	0.539	5.18	0.24	6559	112.00
	3.00	95	76	344	288	80	232	84	30.08	0.540	5.17	0.24	6858	-
	4.30	92	77.5	342	266	80	232	84	30.08	0.524	5.33	0.21	8503	-
Aug. 13	A. M. 9.00	80	73	184	196	80	211	80	30.08	0.348	7.07	0.12	8510	-
	9.15	79	72	182	188	80	203	80	30.08	0.348	7.07	0.12	10118	-

* Period of steady action to day, from 7*h.* a. m. to 2*h.* 30*m.* p. m. = 7*h.* 30*m.*; coal supplied in that time, 673 lbs.; and 15 sets of observations taken; water supplied, 6,107¾ lbs.

MOUNTAIN ANTHRACITE.

Steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 68 feet.
h m.					First charge of coal thrown on grate behind wood; coal small.
4.00	66.6	156	— 9	-	Water 0.18 inch above normal level; commenced firing.
4.45	66.7	148	+29	-	Wood consumed, 79 lbs.; placed second weights on safety valves.
-	67.0	142	26	-	Removed second weights from valves at 5*h*. a. m.; temperature of steam 234°; morning clear; wind NW., light.
-	67.5	139	28		
-	67.1	138	38		
6.23	68.4	135	55	1.415	Air plates opened at 7 o'clock a. m.
7.00	68.0	148	74	1.953	
-	68.8	147	69	1.669	
-	69.6	172	64	2.342	Filled tank at 8*h*. 55*m*. p. m.
9.00	70.4	184	61	2.548	
-	70.0	189	73	2.098	
10.00	71.2	196	76	1.298	In consequence of the tendency of the boiler to priming through the front valve, it is necessary to continue the use of the small additional weights on that valve, causing most of the steam to escape from the back valve, and to give a slight increase of pressure.
-	72.7	204	70	2 675	
-	72.1	212	70	3.030	
11.06	73.2	221	71	2.659	
0.00	71.5	235	66	2.230	Commenced drawing gases from lower flue at 0*h*. 7*m*. p. m.; drew in 28 minutes 100 cubic inches, which gave 0.81 grain of water, 4.86 grains of carbonic acid, and 13.498 cubic inches of oxygen gas; temperature at bath 85°; atmosphere hazy.
-	70.0	246	-	1.685	
1.05	73.6	251	68	2.146	
-	72.4	252	70	1.868	Weather cloudy; wind SW.
-	73.3	247	66	1.748	
2.30	75.9	248	63	2.236	Filled tank at 2*h*. 55*m*. p. m.
-	73.0	249	56	1.584	Air plates closed; contents of ash pit thrown on grate.
-	71.8	250	34	-	Water 1.3 inch above true normal level.
-	70.3	104	—15	-	No fire on grate; morning clear; wind NW., light.
-	69.2	103	—16	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	36.00
Clinker behind bridge - - - - - - - - - -	0.35
Ashes - - - - - - - - - - -	41.25
Ashes behind bridge - - - - - - - - - -	4.50
Total ashes and clinker - - - - - - - - -	82.10
Deduct wood ashes - - - - - - - - - -	0.242
Total waste from coal - - - - - - - - - -	81.858
Coke - - - - - - - - - - - -	24.927

TABLE XIX.—PEACH

Fourth trial—upper damper 4 inches open; air plates closed.

					TURES OF THE									
					Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
Aug. 14	4.25	76	71	150	170	80	179	77	29.99	0.347	7.07	0.10	-	-
	6.30	79	73	144	236	80	[illegible]	76	29.96	[illegible]	5.28	0.19	-	[illegible]
	7.00	78	75	149	216	80	231	78	[illegible]	0.535	5.22	0.18	-	112.50
	7.30	79.5	73.5	148	231	77	228	79.5	29.96	0.511	5.45	0.20	-	-
	8.00	81	74	148	234	77	228	80	29.95	0.515	[illegible]	0.22	-	-
	8.30	82	74	149	246	77	229	82	29.95	0.520	5.37	0.21	-	-
	[illegible]	84	75	155	256	77	230	82.5	29.95	0.523	5.34	0.22	-	106.25
	9.30	84	76	160	264	77	230	84	29.95	0 527	5.30	0.22	[illegible]	-
	10.00	86	76	166	270	77	230	85	29.95	0.535	5.22	[illegible]	345	-
	[illegible]	86	76	[illegible]	264	77	230	85	29.95	0.529	5.28	0.23	760	100.75
	11.00	88	[illegible]	188	282	78	232	86	29.94	0.541	5.16	0.31	845	-
	11.30	88	77	201	282	78	231	86	29.94	0.531	5.26	0.23	1410	-
	P. M.													
	0.00	90	77	212	274	78	231	86	29.93	0.525	5.32	0.22	1717	110.00
	[illegible]	[illegible]	78	226	281	78	230	86	29.92	0.527	5.30	0.22	2186	-
	1.00	[illegible]	78	235	276	78	230	86	29.92	0.526	5.30	0.25	2557	-
	1.30	89	77	244	292	78	230	87	29.89	0.524	5.33	0.26	2975	104.25
	2.00	92	[illegible]	252	284	78	232	87	29.88	0.527	5.30	0.22	3347	-
	2.30	94	80	257	275	82	230	88	29.87	0.515	5.42	0.21	3670	107.50
	3.00	93	79	264	284	82	230	88	29.86	0.533	5.24	0 21	4000	-
	3.30	93	[illegible]	270	276	[illegible]	230	88	29 84	0.529	5.28	0.21	4345	111.25
	[illegible]	[illegible]	80	281	273	82	232	88	29.83	0 521	5.36	0.21	4657	-
	4.30	95	81	284	278	82	231	88	29 83	0.525	5.32	0.21	5031	-
	5.10	92	80	290	279	82	232	88	29.82	0.531	5.26	0.22	5507	-
	5.35	95	81	296	273	84	232	87	29.81	0.521	5.36	0.20	[illegible]	112.50
	6.00	94	80	304	282	84	230	87	29.81	0.519	5.38	0.20	6622	-
	A. M.													
Aug. 15	2.30	76	74	220	210	84	226	80	29.86	0.477	5 74	0.12	6632	-
	3.45	78	73	206	[illegible]	84	210	78	29.87	0.350	7.05	0.16	8327	-

Period of steady action to-day is from 10*h*. 30*m*. a. m. to 5*h*. 20*m*. p. m.=7 hours; coal supplied, 545.5 lbs.; water delivered to boiler in that time, 5,025 lbs.; 14 sets of observations embraced in the same period.

MOUNTAIN ANTHRACITE.

—steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air in reaching grate.	[illegible]	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 121 feet; height of chimney 63 feet.
A. m.					
-	66.9	74	— 9	-	Water 0.15 inch below normal level; commenced firing at 4*h.* 32*m.*; additional weights on valves.
6.30	70.7	65	+ 8	-	Wood consumed, 192½ lbs.; commenced charging with coal; steam at equilibrium.
7.00	71.0	71	—13	-	Additional weights removed from valve; steam blows off.
-	71.2	68.5	+ 3	-	Morning clear; wind SW., light.
-	71.4	67	6		
-	71.0	67	17	-	Coal kept about 5 inches deep on the grate.
9.00	71.8	71	26	-	Moderate fire in small furnace.
-	73.3	86	34	0.424	
-	73.7	80	[illegible]	1.404	Damper reduced to 4 inches.
10.20	72.7	90	34	2.199	
-	72.1	100	50	0.450	
-	73.5	113	51	[illegible]	
11.55	73.0	122	43	1.629	
-	74.4	136	51	2.485	Wind SE., brisk; clear.
-	74.1	145	46	1.966	Fire moderately active; boiler shows symptoms of *priming.*
1 24	73.2	155	62	2.216	
-	75.2	160	[illegible]	1.971	Filled tank at 2*h.* 25*m.* p. m.
2.35	76.1	163	45	1.711	Wind SE., brisk; clear.
-	76.0	171	54	1.775	
3.32	75.0	177	40	1.601	
-	76.4	[illegible]	41	1.653	
-	77.3	189	47	1.981	Fire in small furnace out, and its damper closed.
-	76.6	198	47	1.891	Cloudy; filled tank at 5*h.* 16*m.* p. m.
5.20	77.3	201	[illegible]	2.225	Contents of ash pit thrown on grate.
-	76.1	210	32	-	Water 1 inch above normal level.
-	73.2	144	—16	-	Water below the glass tube of gauge.
-	71.0	126	— 8	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	23.26
Clinker behind bridge	0.362
Ashes	[illegible]
Ashes behind bridge	3.66
Total clinker and ashes	67.932
Deduct wood ashes	0.591
Total waste from coal	67.341
Coke	34.571

TABLE XX.—PEACH

Fifth trial—lower damper 4 inches open; air plates closed;

Date.
Aug. 15
Aug. 16

The period of steady action to-day is from 7*h*. 45*m*. a. m. to 5*h*. 10*m*. p. m.—9*h* 25*m*.; coal, supplied, 861 lbs.; water, 7,844 lbs.; sets of observations, 20.

MOUNTAIN ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of hot air 58.5 feet; height of chimney 63 feet.
h. m.					
3.45	71.0	128	— 8	-	First charge thrown on grate behind wood; water 0.1 inch above normal level; commenced firing.
4.45	69.5	113	+14	-	Second weight on safety valve; wood consumed, 85.5 lbs.
-	69.9	115	58	-	Second weights removed from safety valves; lower damper set at 4 inches at 5*h.* 0*m.* a. m.
5.35	69.5	116	75	-	Morning clear; wind NE., light; rain last night.
-	69.5	118	124		
6.45	69.2	121	162	0.568	
7.45	68.8	127	160	2.989	Filled tank.
-	69.6	144	190	2.274	
-	71.2	157	168	2.765	
8.40	72.7	177	177	3.169	
9.30	72.4	195	157	3.564	Small additional weights on valves, to prevent priming.
-	71.2	210	157	4.515	Fire in vigorous action.
-	69.7	227	128	4.034	
11.00	73.0	245	108	3.522	
-	71.2	252	108	3.280	Filled tank at 11*h.* 47*m.* a. m.
11.47	71.5	258	108	2.685	
-	70.9	256	114	2.484	
-	69.7	254	118	2.315	
1.30	68.4	256	108	3.062	
-	70.9	260	188	3.377	Wind NW., brisk; clear.
-	69.4	256	116	2.090	
3.00	69.4	257	106	2.560	
-	70.9	257	108	2.436	Filled tank at 3*h.* 35*m.* p. m.
4.10	71.5	255	92	1.938	
-	68.4	256	130	2.803	
-	68.4	256	128	2.145	
5.10	69.7	264	102	2.671	
-	70.0	264	80	-	Water in boiler left at 1.5 inch above normal level.
-	66.6	156	—36	-	Very little fire on grate.
-	66.6	154	—26	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	44.00
Clinker behind bridge - - - - - - - -	0.433
Ashes - - - - - - - - - - -	47.00
Ashes behind bridge - - - - - - - - -	5.56
Total ashes and clinker - - - - - - - -	96.993
Deduct wood ashes - - - - - - - - -	0.262
Total waste from coal - - - - - - - -	96.731
Coke - - - - - - - - - - -	28.523

TABLE XXI.—PEACH

Sixth trial—upper damper 3 inches open; air plates closed;

Period of steady action to-day, from 10*h*. 10*m*. a. m. to 6*h*. 42*m*. p. m. = 8*h*. 32*m*.; weight of coal supplied, 651 lbs.; water, 7,617 lbs.; sets of observations taken, 17.

MOUNTAIN ANTHRACITE.

small furnace in action, and additional weights on safety valves.

-Grate surface 14.07 square feet; length of t air 121 feet; height of chimney 63 feet.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before [illegible] grate.			
h. m.					
5.40	66.6	184	—[illegible]	-	First charge thrown on grate behind wood; water in boiler 0.1 inch below normal level; commenced firing at 5h. 40m. a. m.; morning cloudy; wind N., light.
6.30	67.1	1[illegible]			
-	66.2	121	+10	-	Wood consumed, 97 lbs.; 3 weights (94½ lbs.) on valves.
7.30	66.5	129	8	-	Filled tank; fire getting into moderate action.
-	68.0	126	6		
-	66.8	123	13	-	Steam blows off.
-	69.6	124	19		
-	66.9	125	26		
9.00	66.5	128	46	0.276	In consequence of the tendency of the boiler to priming, it was necessary at 10h. a. m. to load down the front valve, and reduce the water level.
-	66.5	144	69	-	
10.30	65.7	168	90	2.501	As no water appears to escape with the steam from back valve, water in boiler will be gradually brought up to usual height.
-	65.7	166	56	[illegible]	
11.07	68.2	206	55	3.629	Water at usual height above normal level.
0.00	68.2	214	60	1.748	Filled tank.
-	67.5	237	60	[illegible]	
-	68.4	266	59	1.658	
1.15	[illegible]	279.5	68	2.560	
-	70.[illegible]	289	68	2.909	The coal in drying apparatus weighs now 27 lbs. 7½ oz.
2.25	74.2	[illegible]	69	2.177	
-	[illegible]	30[illegible]	62	2.268	
3.30	69.5	316	56	[illegible]	Wind NW., light.
-	69.3	[illegible]	52	1.165	Wind NE., light.
4.30	68.5	327	37	[illegible]	
-	68.8	323	39	1.236	Filled tank at 4h. 50m. p. m.
-	69.8	326	39	1.642	
5.50	70.6	335	30	1.801	
-	72.1	340	33	1.727	Combustion beginning to be much impeded by the clinker accumulated on the grate, and which is difficult to remove, from adhesiveness.
6.42	72.4	349	28		
-	69.1	33[illegible]	35	-	Contents of ash pit thrown on grate at 7h. p. m.; at 8h. 30m. p. m., water 2.9 inches below normal level.
-	70.0	317	32	-	Water brought to 1.2 inch above normal level; fire still on grate.
-	66.6	1[illegible]4	— 1	-	Filled tank.
-	71.0	17[illegible]	± 0	-	Water in boiler adjusted.

RESIDUA.

Clinker - - - -	Lbs. 39.000	Total ashes and clinker - -	Lbs. 93.325
Clinker behind bridge - -	" 0.445	Deduct wood ashes - -	" 0.298
Ashes - - - -	" 48.250	Total waste from coal - -	" 93.027
Ashes behind bridge - -	" 5.630	Coke - - - - -	" 39.024
Total ashes and clinker - -	" 93.325	Soot from flues - - -	" 6.

TABLE XXII.—DEDUCTIONS FROM

Experiments on Peach

	Nature of the data furnished by the respective tables.	1st Trial. (Table XVI.)	2d Trial. (Table XVII.)	3d Trial. (Table XVIII.)
		Aug. 10.	Aug. 11.	Aug. 12.
1	Total duration of the experiment, in hours - -	29.25	22 083	29.25
2	Duration of steady action, in hours - - -	10.083	6 50	7.50
3	Area of grate, in square feet - - -	14.07	14.07	14.07
4	Area of heated surface of boiler, in square feet -	377.5	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	18.75	18.75	18.75
6	Number of charges of coal supplied to grate -	15.0	10.0	10.0
7	Total weight of coal supplied to grate, in pounds -	1585.75	1099.0	1114.0
8	Pounds of coal actually consumed - - -	1566.395	1075.825	1089.073
9	Pounds of coal withdrawn and separated after trial -	19.355	23.175	24.927
10	Mean weight, in pounds, of one cubic foot of coal -	52.858	54.95	55.7
11	Pounds of coal supplied per hour, during steady action	103.83	102.384	89.733
12	Pounds of coal per square foot of grate surface, per hour	7.379	7.276	6.377
13	Total waste, ashes and clinker, from 100 lbs. coal -	6.187	6 993	7.516
14	Pounds of clinker alone, from 100 pounds coal -	3.014	3.1572	3.3257
15	Ratio of clinker to the total waste, per cent. - -	48.079	45.142	44.247
16	Total pounds of water supplied to the boiler - -	14565.0	10163.0	10118.0
17	Mean temperature of water, in degrees Fahrenheit -	76°.8	77°.3	79°.0
18	Pounds of water supplied at the end of experiment, to restore level - - - - - -	2180.0	525.0	1608.0
19	Deduction for temperature of water supplied at end of experiment, in pounds - - - - -	288.0	67.0	206.0
20	Pounds water evaporated per hour, during steady action	916.16	1090.30	814.356
21	Cubic feet of water per hour, during steady action -	14.66	17.44	13.029
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - -	2.427	2.8855	2.157
23	Pounds of water per square foot, by a mean of several observations - - - - - -	2.414	2.888	2.146
24	Water evaporated by one of coal, from initial temp. (a) final result - - - - - -	9.1145	9.3842	9.1013
25	Water evaporated by one of coal, from initial temp. (b) during steady action - - - - -	8.8233	10.6491	9.0753
26	Pounds of fuel evaporating one cubic foot of water -	6.8572	6.6602	6.7797
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - -	80°.12	85°.53	86°.81
28	Mean temperature of wet bulb thermometer, during steady pressure - - - - - -	73°.31	74°.41	75°.19
29	Mean temperature of air, on arriving at the grate -	327°.0	323°.59	292°.45
30	Mean temperature of gases, when arriving at chimney	285°.26	298°.31	299°.47
31	Mean temperature of steam in the boiler - -	232°.83	232°.00	232°.06
32	Mean temperature of attached thermometer - -	75°.44	80°.65	80°.44
33	Mean height of barometer, in inches - -	30.007	30.04	30.002
34	Mean number of volumes of air in manometer -	5.003	5.172	5.09
35	Mean height of mercury in manometer, in atmospheres	.5573	.5398	.5481
36	Mean height water in syphon draught gauge, in inches	.2824	.2823	.2826
37	Mean temperature of dew point, by calculation -	70°.73	70°.55	71°.32
38	Mean gain of temperature by air before reaching grate	246°.88	138°.06	205°.44
39	Mean difference between steam and escaping gases -	52°.2	69°.08	67°.57
40	Water to one of coal, corrected for temperature of water in cistern - - - - - -	9.08[illegible]	9.3524	9.0693
41	Water to one of coal, from 212°, corrected for temperature of water in cistern - - -	10.274	10.578	10.2407
42	Pounds of water, from 212°, to one cubic foot of coal	543.08	581.27	570.39
43	Water, from 212°, to one pound of combustible matter of the fuel - - - - - -	10.962	11.3735	11.0725
44	Mean pressure, in atmospheres, above a vacuum -	1.468	1.4287	1.4514
45	Mean pressure, in pounds per sq. in., above atmos. -	6.911	6.3309	6.6664
46	Condition of the air plates at the furnace bridge -	Closed.	Closed.	Open.
47	Inches opening of damper, (U. upper, L. lower) -	U. 8	U. 8	U. 8

TABLES XVI, XVII, XVIII, XIX, XX, XXI.

Mountain anthracite coal.

4th Trial. (Table XIX.)	5th Trial. (Table XX.)	6th Trial. (Table XXI.)	Averages.	Remarks.
Aug. 14.	*Aug.* 15.	*Aug.* 16.		
23.333	25.667	26.917		
7.0	9.417	8.583		
14.07	14.07	14.07		
377.5	287.00	377.5		
18.75	18.75	18.75		
9.0	13.0	13.0		
974.5	1372.5	1386.0		
939.629	1342.977	1356.976		
34.871	28.523	29.024	26.646	With the upper damper drawn but 4 inches, the unburnt coal left is 34.87 lbs.; in the other five trials, the mean amount is 26 lbs.
54.138	52.769	53.308	53.954	
77.928	91.44	99.73	91.174	
5.546	6.499	7.088	6.694	
7.166	7.187	6.855	6.969	
2.4852	3.2979	2.8987	3.0298	
34.678	45.849	42.238	43.474	
8327.0	12191.0	12246.0		
80°.8	82°.5	81°.4		
1695.0	1964.0	1957.0		
213.0	247.0	254.0		
717.857	832.98	892.65	877.384	
11.485	13.326	14.28	14.037	
1.901	2.902	2.3645	2.347	Fifth trial omitted in making the averages, on account of the difference in the amount of heating surface.
1.908	2.884	2.249		
8.6353	8.887	8.8373	8.9933	
9.2117	9.11	8.95	9.3032	
7.2378	7.0328	7.0723	6.94	
90°.25	88°.17	89°.59		
79°.06	74°.83	74°.19		
231°.69	308°.09	349°.67	305°.38	
277°.12	362°.61	302°.0	292°.43	Fifth trial omitted, for the reason above assigned.
230°.69	231°.87	251°.09		
86°.62	83°.26	84°.0		
29.895	29.93	30.029		
5.291	5.206	3.499		
.5279	.5364	.7099		
.2271	.3062	.2061	.2626	Fifth and sixth trials left out of average.
74°.41	70°.32	68°.91		
141°.44	219°.92	260°.08	201°.97	
48°.28	135°.9	51°.59	57°.74	Fifth trial omitted.
[illegible]	8.8507	8.8634	8.9602	
9.6962	9.959	9.923	10.1118	
524.93	525.53	528.97	545.695	
10.440	10.7313	[illegible]	10.8702	
1.4059	1.424	2.0602	1.4356	Sixth trial omitted in this average.
5.9921	6.262	15.657	6.4325	Sixth trial omitted in making this average, on account of excess of pressure.
Closed.	Closed.	Closed.		
U. 4	L. 4	U. 8		

No. 5.

Anthracite sent by the Lehigh Coal and Navigation Company, Philadelphia.

"Office of the Lehigh Coal and Navigation Co.,
"*Philadelphia, July* 13, 1843.

"Sir: I have taken the liberty of directing to your address four hogsheads, containing two tons of our coal, that it may be submitted to the experiments now making (I believe under your superintendence) for testing the comparative value for generating steam of different kinds of coal. Our intention in making this shipment, of which a bill of lading is hereto annexed, was recently communicated to you by Mr. Josiah White. When the experiments are concluded, we hope to learn the result from you.

"I remain, sir, yours, very respectfully,
"J. COX, *President.*

"Prof. W. R. Johnson,
"*Navy Yard, Washington, D. C.*"

The aspect and character of this coal leave no doubt that it will remain for any desired length of time, either under shelter or in the open air, without material change.

The coal was received generally in lumps, requiring to be reduced in order to be burned advantageously on the grate. Its aspect is that of most of the harder anthracites, possessing a deep black color, shining uneven and splintery fracture, with occasional exposure of conchoidal forms; a striated rather grayish appearance, generally indicative of considerable portions of earthy impurity, marks certain surfaces. The seams of deposition are seldom followed by the fractures.

The specific gravity of two specimens was found to be 1.6126 and 1.5679, from which the calculated weights per cubic foot are 100.79 and 97.99 pounds, respectively, or, on an average, 99.39 pounds.

Thirty-six trials of the weight per cubic foot, in the state in which the coal was received, gave, as will be seen on reference to the tables of trial for evaporative power, 55.316 pounds, or 0.5566 part as much as that computed from the specific gravity of the two specimens.

From the above, it appears that the space required for the stowage of a ton is $\frac{2240}{55.316} = 40.49$ cubic feet.

Two boxes of this anthracite were reduced to egg size; the first weighed 119.5 pounds, and the second 115 pounds—proving that the mean weight per cubic foot in this state is 58.625 pounds, or that the gross ton would occupy only 38.2 cubic feet.

From an inspection of the columns in the tables under the head of "weight of charges of coal," it will be observed that, in a few cases in which the charge box was nearly filled by one or two large lumps, the weight per cubic foot was as high as 60, and even 61 pounds. But a cargo made up wholly of such lumps would not probably weigh much, if at all, more than the average 55.316 pounds per cubic foot, as already obtained. The moisture from specimen *a* was found to be 2.347 per cent. The trial of this coal for moisture, in the apparatus connected with the boiler, showed no appreciable loss from drying.

The total volatile matter, including water, was found to be 5.285 per

cent. The residue, after incinerating a portion of the first specimen, of which the specific gravity is given above, amounted to 6.663 per cent.

The ashes obtained by analysis are nearly white, or only marked by a slight grayish tint.

By an inspection of the tables of experiments on evaporation, it will be found that there were burned of this anthracite 3838.25 pounds; and that from all the trials there were obtained of *ashes* 235.76 pounds, and of clinker 42.25 pounds—total, 278.01 pounds = 7.253 per cent. A reduction of the combustible matter remaining in the ashes caused a loss of 26.91 per cent. of their weight—leaving only 171.82 pounds of ashes; and the pulverization and exposure of a portion of the clinker to reincineration at a bright red heat caused a loss of 8.89 per cent., reducing it to 38.49 pounds for the whole amount of coal consumed. By similar treatment, 6 pounds of soot were reduced to 3.156 of ashes. Thus it appears that the true total waste is 213.496 pounds, or 5.562 per cent.

From these data it should seem that the Lehigh anthracite is composed of—

Volatile matter	5.285 or	5.285
Earthy matter	5.562 or	6.663
Fixed carbon	89.153 or	88.052
	100.	100.

The clinker of this coal is made up of semi-vitrified matter and fragments of slate nearly white. It is usually in small fragments, and the agglutination is not sufficient to cause much obstruction of the grate. Its weight per cubic foot is only 35.35 pounds; while that of the ashes, including the fine anthracite, is 46.55 pounds for the same bulk, and that of the dust from the flues is 19.51 pounds.

From the table of deductions relative to this coal, the total waste is found to have been on an average 7.2235 per cent. Hence the proportion of combustible matter, which escapes actual combustion and separation by the sieve, is about 1⅔ per cent.

A trial of this coal, by means of litharge, gave 27.377 times its weight of lead reduced. The combustion is difficult to be brought to its maximum activity, as evinced by the fact that, on an average, it required 3.268 hours from the time the wood was withdrawn from the grate, and the regular charging with coal had been commenced, to bring the boiler to its regular action; and the impracticability of continuing the combustion till the whole of the coal is consumed, is proved by the amount withdrawn after each trial, which averaged 36.125 pounds. The character of the residuum of this coal indicates its adaptation to use in close stoves and furnaces, in which a high temperature is required. There is but a moderate quantity of oxide of iron, and the other ingredients show but little tendency to become vitrified.

In the smith's fire, this last-mentioned circumstance would be rather objectionable than otherwise, as it would tend to accumulate cinders in the fire, without affording facilities for their removal—such as a speedy reduction to a fused mass gives to the workman. The analysis of gases from the chimney showed a large proportion of unchanged air—due, in some degree, probably, to the obstruction which the air meets in arriving at the surface of the coal, from the coat of ashes which covers its surface during combustion.

TABLE XXIII.—LE

First trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Oct. 31	4.15	44	38	108	136	54	154	46	30.30	0.376	6.79	0.15	-	-
	5 05	42	38	112	214	52	190	44.5	30.33	0.378	6.77	0.30	-	-
	7.07	41.5	37	126	242	53	227	43	30.35	0.522	5.32	0.30	-	110.50
	7.30	41	36	126	233	53	234	43	30.37	0.572	4.86	0.31	-	118.00
	8.00	40.5	36	122	231	53	232	42	30.39	0.542	5.12	0.35	168	106.25
	8.30	43	38	123	243	53	233	42	30.39	0.553	5.04	0.31	247	-
	9.00	44	38	130	255	53	233	43	30 39	0.564	4.94	0.34	417	-
	9.30	46	39	142	266	53	234	45	30.40	0.560	4.98	0.34	820	106.50
	10.00	46	39	154	277	52	234	46	30.40	0.566	4.92	0.38	1142	-
	10 45	48	40	174	286	52	234	47	30.40	0.570	4.88	0.39	1620	118.25
	11.15	48	40	184	259	50	234	48	30.40	0.564	4.94	0.39	1988	-
	11.45	50	42	199	284	50	235	48	30.39	0.555	5.03	0.38	2310	110.50
	P. M. 0.15	51	43	208	288	50	234	48	30 38	0.562	4.96	0.37	2730	-
	0.45	53	44	218	270	50	235	48	30.38	0.562	4.96	0.36	3035	-
	1.15	53	44	234	270	50	234	48	30 38	0.560	4.98	0.36	3345	-
	1.45	56	46	257	284	50	235	48.5	30.37	0.563	4.95	0.40	3684	122.25
	2.15	55	46	262	284	51	234	50	30.37	0.564	4.94	0.40	4018	-
	2.45	56	47	264	282	51	234	51	30.37	0.563	4.95	0.36	4350	120.75
	3.25	57	49	272	276	51	234	51	30 37	0.562	4.96	0.36	4793	-
	3.45	57	49	270	282	52	234	51	30.37	0.552	5.06	0.33	5113	-
	4.15	57	49	277	281	52	234	51	30.37	0.560	4.98	0.36	5360	120.50
	4.45	56	46	280	284	53	234	51	30.37	0 564	4.94	0.36	5785	-
	5.00	56	47	284	269	53	232	51	30.37	0.545	5.12	0.30	6345	-
	7.30	46	41	268	256	52	232	47	30.39	0.550	5.07	0.30	6345	-
	8.40	45	40	262	240	52	230	46	30.39	0.550	5.07	0.27	7755	-
Nov. 1	A. M. 5.30	38	34	182	189	51	223	38	30.37	0.465	5.90	0.23	7755	-

Period of steady action from 9*h*. 32*m*. a. m. to 3*h*. 52*m*. p. m.—6*h*. 20*m*.; coal supplied in that time, 592.25 lbs.; water, 4,329 lbs; sets of observations taken, 12.

HIGH ANTHRACITE.

Steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 63 feet.
h. m.					
-	21.7	64	—18	-	Commenced firing at 4*h.* 28*m.* a. m.; fire lighted in small furnace at same time.
-	27.6	70	+24	-	Morning clear; wind NW., light.
7.15	24.2	84.5	15	-	Consumed 315.5 lbs. of wood; commenced charging with coal at 7*h.* 15*m.* a. m.
7.27	20.6	85	— 1	-	Steam escapes at 7*h.* 36*m.*; upper damper set at 8 inches at 7*h.* 40*m.* a. m.
8.00	22.25	81.5	— 1	0.889	
-	24.7	80	+10	0.425	
-	21.7	86	22	0.900	
9.32	20.8	96	32	2.135	Fire in good action at 9*h.* 55*m.* a. m.
-	20.8	108	43	1.706	
10.45	20.6	126	52	1.688	
-	20.6	136	35	1.949	Filled tank at 11*h.* 2*m.* a. m.
11.49	25.3	149	49	1.706	
-	27.4	157	54	2.225	
-	27 4	165	35	1.615	
-	27.4	181	36	1.642	
1.17	30.0	201	49	1.796	Placed 28 lbs. of this coal in drying apparatus; one large lump nearly fills the box in the 7th charge.
-	31.8	207	50	1.770	
2.50	33.6	208	48	1.759	One large lump in 8th charge.
-	38.5	215	42	1.760	Filled tank at 3*h.* 40*m.* p. m.
-	38.5	213	48	2.543	
3.52	38.5	220	47	1.308	Two large lumps in 9th charge.
-	30.0	224	50	2.251	Contents of ash pit thrown on grate.
-	33.6	228	37	-	Water in boiler left at 1.25 inch above normal level.
-	30.1	222	24	-	Steam still escapes copiously; water 0.35 inch below normal level; water at 8*h.* 40*m.* left 0.65 inch below normal level.
-	28.4	217	10		
-	19.8	144	—34	-	Water needing no adjustment.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	14.25
Ashes - - - - - - - - - - - -	54.75
Ashes behind bridge - - - - - - - - -	1.50
Total clinker and ashes - - - - - - - -	70.50
Deduct wood ashes - - - - - - - - -	0.968
Total waste from coal - - - - - - - -	69.532
Coke - - - - - - - - - - - -	34.5

TABLE XXIV.—LE

Second trial—upper damper 3 inches open; air plates open;

	Volumes of air in manometer.	Height of water [illegible] syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
5	6.20	0.32	-	103.25
6	4.72	0.31	-	103.50
2	5.15	0.30	153	-
0	5.16	0.30	310	-
0	5.16	[illegible]	[illegible]	-
7	5.10	0.30	336	107.00
3	5.04	0.31	413	-
1	5.16	[illegible]	653	103.25
6	5.02	0.32	729	-
6	5.00	0.32	1065	108.25
5	[illegible]	0.33	1304	-
4	4.94	0.35	1617	-
4	5.03	0.33	1868	106.25
6	5.01	0.34	2313	-
3	5.04	0.35	2565	-
7	5.00	0.33	2579	111.00
7	5.10	0.31	2993	-
2	4.96	0.34	3287	106.50
6	5.11	[illegible]	3528	-
8	5.00	0.35	3781	106.25
1	5.26	0.30	4372	-
3	5.04	0.28	4578	-
	-	-	5049	-
5	5.12	0.30	5717	-
6	5.02	0.27	5989	-
7	5.10	0.23	-	-
5	6.20	0.20	6817	-

The period of steady action this day from 11*h.* 16*m.* a. m. to 4*h.* 15*m.* p. m. = 4*h.* 59*m.*; coal supplied in that time, 432 lbs.; water, 2,775.5 lbs.; sets of observations taken, 11.

HIGH ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS —Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Morning clear; wind NE., light.
6.54	-	135	—36	-	First charge of coal thrown on grate behind wood; commenced firing.
7.30	-	113	+16	-	Wood consumed, 81¾ lbs.; second weight removed from safety valve at *7h. 39m.*
-	28.8	108	+ 4	0.801	Set damper at 8 inches.
-	31.8	104	— 3	0.931	
-	30.9	102	— 9		
9.14	31.9	101	± 0	0.042	
-	33.3	98	+14	0.460	Wind SE.; clear.
10.30	33.2	98	18	1.271	
-	33.2	100	38	0.396	Air plates opened at 11*h.* 5*m.*; fire in good action.
11.16	36.6	104	38	1.498	Filled tank at 11*h.* 37*m.* a. m.
-	33.3	116	44	1.564	Thick bed of coal, well ignited, on grate.
-	38.2	125	52	1.658	Clouding over; clouds flying from south.
0.40	36.6	132	38	1.308	
-	39.6	138	40	2.384	
-	38.2	140	44	0.275	
2.09	39.8	143	44	1.183	
-	39.8	152	40	2.193	
3.10	42.6	159	55	1.168	Clear; filled tank at 3*h.* 45*m.* p. m.
-	41.4	165	44	1.915	
4.15	42.9	174	58	1.340	A part of contents of ash pit thrown on grate.
-	39.8	200	23	-	Contents of ash pit thrown on grate at 4*h.* 50*m.*; water left in boiler at 1.5 inch above normal level.
-	39.8	198	32	1.048	Water in boiler at normal level.
-	-	-	-	-	Water in boiler brought 1.1 inch above normal level.
-	36.6	198	20	-	Water 0.8 inch below normal level.
-	36.6	194	12	-	Water left in boiler 1 inch above normal level.
-	45.1	140	—23	-	Fire on grate; water 2.3 inches below normal level; morning rainy.
-	42.4	143	—22	-	Water adjusted; considerable ignited anthracite removed from grate.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	9.00
Ashes - - - - - - - - - - -	60.75
Ashes behind bridge - - - - - - - -	1.35
	71.10
Deduct wood ashes - - - - - - - - -	0.251
Total waste from coal - - - - - - - -	70.849
Coke - - - - - - - - - - -	49.25

TABLE XXV.—LE

Third trial—upper damper 10 *inches open; air plates closed;*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Nov. 2	6.30	50	48.5	196	194	52	220	50	29.95	0.426	6.29	0.22	-	111.00
	7.20	53	51	184	254	52	231	50	29.95	0.588	4.70	0.25	-	102.00
	7.30	51.5	48.5	179	250	52	235	50	29.96	0.588	4.70	0.32	-	-
	8.00	52	49	170	247	52	230	50	29.97	0.537	5.19	0.30	242	-
	8.30	53	49	156	251	52	230	50	29.97	0.536	5.20	0.31	320	107.50
	9.00	54	49	170	258	53	232	50	29.97	0.536	5.20	0.30	485	-
	9.45	55	50	173	274	53	232	53	29.96	0.549	5.08	0.34	737	104.00
	10.00	55	49	174	277	50	233	54	29.95	0.550	5.07	0.32	737	-
	10.30	56	50	182	273	50	232	54	29.95	0.549	5.08	0.31	1067	-
	11.00	58	52	188	283	50	233	54	29.96	0.551	5.06	0.34	1377	112.25
	11.30	58	52	198	290	50	232	55	29.95	0.539	5.18	0.34	1692	-
	P. M. 0.00	60	53	206	289	50	233	55	29.94	0.547	5.10	0.34	2017	-
	0.30	60	52	222	288	50	233	56	29.93	0.556	5.02	0.33	2263	111.50
	1.10	61	53	233	270	50	232	56.5	29.94	0.538	5.18	0.32	2687	-
	1.30	64	55	261	298	51	233	57.5	29.93	0.558	5.00	0.43	2967	-
	2.00	64	55	280	320	51	234	58	29.92	0.567	4.90	0.33	3165	114.00
	2.30	64	55	272	293	52	234	60	29.91	0.562	4.96	0.34	3822	-
	3.10	64	55	300	296	52	233	60	29.91	0.561	4.97	0.32	4327	115.25
	3.30	67	56	309	296	54	232	60	29.91	0.560	4.98	0.32	4546	-
	4.00	66	55	324	280	54	232	60	29.91	0.553	5.04	0.30	4880	-
	5.15	57	50	300	274	54	231	60	29.92	0.547	5.10	0.28	5371	-
	5.30	57	50	294	264	54	229	59	29.90	0.534	5.21	0.25	6084	-
	8.15	56	48	272	244	54	230	55	29.95	0.551	5.06	0.26	6084	-
	8.47	56	48	264	240	54	230	55	29.96	0 543	5.14	0.28	6636	-
	11.10	55	46.5	234	231	54	230	53	29.96	0.553	5.04	0.35	6801	-
	A. M.													
Nov. 3	6.20	44	39	192	192	54	223	46	30.15	0.492	5.64	0.23	6803	-

The period of steady action extends from 10*h.* 57*m.* a. m. to 2*h.* 40*m.* p. m.=3*h.* 43*m.*; coal supplied, 340.75 lbs.; water, 2,644 lbs.; and of observations, 8 sets were taken.

HIGH ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated air 121 feet; height of chimney 63 feet.
h. m.					Heavy rain last night; morning clear; wind W., light.
6.30	43.9	146	—26	-	First charge thrown on grate behind wood; commenced firing.
7.20	48.6	131	+23	-	Consumed 86.5 lbs. of wood.
-	44.4	127.5	15	-	Steam escapes by removing 2d weight from safety valve.
-	45.1	118	17	1.282	
8.27	43.8	103	21	0.411	
-	42.4	116	26	0.873	Ash pit doors, that had been open, now closed.
9.15	43.8	118	42	-	Wind NW., brisk; clear; water 0.3 inch above normal level.
-	41.1	119	44	0.667	Filled tank.
-	42.6	126	41	1.748	
10.57	45.4	130	50	1.642	Fire in good action.
-	45.4	140	58	1.668	
-	45.7	146	56	1.721	
0.16	43.2	162	55	1.303	
-	44.7	172	48	1.685	
-	46.7	197	65	2.225	Ash pit doors opened from 1*h.* 15*m.* to 1*h.* 30*m.* p. m.; pressure rises.
1.36	46.7	216	86	1.048	Took 2d weight from back valve at 2*h.* p. m.; again opened ash pit doors at 2*h.* 10*m.* p. m.
-	46.7	208	59	3.481	
2.40	46.7	236	63	2.006	Filled tank at 3*h.* 25*m.* p. m.
-	46.5	242	64	1.740	
-	45.0	258	48	1.817	Contents of ash pit thrown on grate at 3*h.* 40*m.* p. m.; ash pit doors closed at 4*h.* p. m.
-	41.4	243	43	1.021	Damper reduced to 4 inches.
-	41.4	237	35	-	Water left at 1.45 inch above normal level.
-	36.8	216	14	-	Water 0.5 inch below normal level.
-	36.8	208	10	-	Double weighted safety valves to fill up boiler; water left 0.7 inch above normal level.
-	33.4	179	1	-	Wind boisterous, NW.; water left 0.5 inch above normal level.
-	26.2	148	—31	-	Water in boiler needs but little adjustment.

RESIDUA.

	Pounds.
Clinker	6.75
Ashes	48.00
Ashes behind bridge	1.26
Total clinker and ashes	56.01
Deduct wood ashes	0.265
Total waste from coal	55.745
Coke	27.5

TABLE XXVI.—LE

Fourth trial—upper damper 10 *inches open; air plates removed; steam*

Date.	Hour.	TEMPERATURES OF TI									Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.								
	h. m. A. M.													
Nov. 3	6.20	44	39		192	54	223	46	30.15	0.492	5.64	0.23	–	109.25
	6.50	47.5	41		235	54	231	45	30.16	0.566	4.72	0.32	–	110 25
	7.30	48	41		222	54	236	46	30.16	0.566	4.72	0.29	–	–
	[illegible]	49	42		221	54	232	45.4	30.18	0 543	5.14	0.29	140	107.75
	8.35	48	41		230	54	232	45	30.18	0 556	5 01	0.31	326	–
	[illegible]	48	[illegible]		222	54	232	46	30.17	0.549	5.08	0.31	[illegible]	–
	9.30	49	42		240	54	233	46	30.17	0.564	[illegible]	0.32	397	–
	10.00	48	41		254	54	233	47	30 17	0.568	[illegible]	0.35	474	107.50
	10.30	50	43		265	54	233	48	30.16	[illegible]	[illegible]	0 34	711	106.50
	11.00	51	43	Thermometer had been deranged	297	50	234	48	[illegible]	0.584	4.74	[illegible]	711	–
	11.30	51	[illegible]		320	51	235	[illegible]	30.16	0.576	4.60	0 40	1284	–
	P. M.													
	0.00	53	45		[illegible]	51	234	48	30.15	0.570	4 69	0 50	1859	120.50
	0.30	53	[illegible]		304	50	235	48	30 14	0.584	4 74	0 40	2371	112.75
	1.00	58	50		307	51	236	49	30.13	0.584	4.74	0 44	2695	–
	1.30	56	[illegible]		309	51	235	49	30.12	0 584	4.74	0.45	3209	119.50
	2.00	56	47		339	52	236	50	30.13	0.596	4.62	0.54	3774	–
	2.50	58	[illegible]		310	52	[illegible]	50	30.13	0.578	4 80	[illegible]	5066	106.75
	3.10	56	47		329	52	236	50	[illegible]	0.596	4.62	0 52	5066	–
	3.40	57	48		304	[illegible]	234	50	30.13	0.578	4 80	0.40	5600	117.75
	4.00	58	50		314	52	236	51	30.13	0.584	4.74	0.42	5934	–
	4.30	59	50		330	52	235	51.5	30.15	0.580	4 77	0.42	6430	–
	5.05	51	43		290	52	233	51.5	30.14	0.575	4.83	0.38	7030	–
	5.25	52	43		275	52	234	51	30.16	0.580	4.78	0.33	7433	–
	7.40	46	[illegible]		260	52	232	48	30.17	0.556	5.01	0.28	7433	–
	8.12	46	41		256	52	230	47	30.17	0.555	5.02	0.27	8055	–
	A. M.													
Nov. 4	6.45	[illegible]	[illegible]		194	50	224	42	30.19	0.602	[illegible]	0 21	8057	–
	7.20	40	36		192	50	217	41	30.19	0.414	6.14	0.21	8473	–

Time of steady action from 10*h*. 20*m*. a. m. to 3*h*. 28*m*. p. m. = 5*h*. 8*m*.; coal supplied, 677.06 lbs.; water, 4,919 lbs.; sets of observations, 10.

HIGH ANTHRACITE.

thrown into chimney; small furnace in action, and ash pit doors open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated air 121 feet; height of chimney 68 feet.
h. m.					Morning clear; wind NW., brisk.
6.20	26.2	-	—31	-	First charge thrown on grate behind wood; commenced firing; water 0 2 inch below normal level.
6.55	24.4	-	+ 4	-	Wood consumed, 70.25 lbs.; after wood was withdrawn, manometer sunk to 0.568.
-	25.5	-	—14	-	Second weight removed from valve, when pressure had got up again.
7.58	27.5	-	—11	0.741	
-	25.5	-	— 2	0.395	
-	29.7	-	—10	0 520	
-	27.5	-	+ 7	0.471	
9.35	25.5	-	21	0 407	
10.20	29.5	-	32	-	Water 0.6 inch above normal level; filling tank.
....	....		....	....	
-	27.4	-	63	0.627	Filled tank; fire in good action; drew 100 cubic inches of gases in 79 minutes at intervals from 11*h*. 4*m*. a. m. to 3*h*. 10*m*. p. m., which gave water, 0; carbonic acid, 2.92 grains; and oxygen, 17.5 cubic inches; mean temperature 49° at bath.
-	27.4	-	85	3.036	
11.45	31.3	-	72	3 046	
0.25	31.3	-	69	2.183	
-	40.1	-	71	2.246	Fire in fine action.
1.14	36.8	-	74	2.723	A charge of this coal (8 lbs.) reduced to egg size just refilled the box; = 119.5 lbs.
-	33.6	-	103	2.994	Another charge of this coal, egg size, weighed 115 lbs.
2.20	34.0	-	75	-	Water 0.8 inch above normal level; coal from ash pit thrown on grate.
-	33.6	-	92	2.933	Filled tank at 3*h*. 27*m*.
3.28	35.5	-	70	2.829	
....			....	....	
-	40.1	-	78	2.654	
-	39.0	-	95	2.628	Contents of ash pit thrown on grate; ash pit doors closed.
-	27.4	-	57	-	Water at 0.4 inch above normal level; damper reduced to 4 inches.
-	25.3	-	41	-	Steam allowed to escape from back valve; water 1.4 inch above normal level.
	....				
-	30.1	-	28	-	Water 0.85 inch below normal level; double weighted back valve.
-	30.1	-	26	-	Water left 0.6 inch above normal level.
-	28.8	-	—30	-	Water 1.15 inch below normal level; morning cloudy.
-	23.9	-	—25	-	Water brought to proper level.

RESIDUA.

	Pounds.
Clinker	12.25
Ashes	68.25
Ashes behind bridge	1.64
Total clinker and ashes	82.14
Deduct wood ashes	0.216
Total waste from coal	81.924
Coke	33 25
Soot	6 00

TABLE XXVII.—DEDUCTIONS FROM

Experiments on Le

	Nature of the data furnished by the respective tables.	1st Trial. (Table XXIII.)	2d Trial. (Table XXIV.)
		Oct. 31.	*Nov.* 1.
1	Total duration of the experiment, in hours - - -	25.25	23.217
2	Duration of steady action, in hours - - - -	6.333	4.963
3	Area of grate, in square feet - - - -	14.07	14.07
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	18.75	18.75
6	Number of charges of coal supplied to grate - -	9.0	9.0
7	Total weight of coal supplied to grate, in pounds - -	1033.5	957.25
8	Pounds of coal actually consumed - - - -	999.0	908.0
9	Pounds of coal withdrawn and separated after trial - -	34.5	49.25
10	Mean weight, in pounds, of one cubic foot of coal - -	57.4166	53.1805
11	Pounds of coal supplied per hour, during steady action -	93.518	108.418
12	Pounds of coal per square foot of grate surface, per hour -	6.647	7.706
13	Total waste, ashes and clinker, from 100 pounds of coal -	6.96	7.802
14	Pounds of clinker alone, from 100 pounds of coal - -	1.407	0.9879
15	Ratio of clinker to the total waste, per cent. - -	20.215	12.661
16	Total pounds of water supplied to the boiler - -	7755.0	6817.0
17	Mean temperature of water, in degrees Fahrenheit - -	51°.4	50°.5
18	Pounds of water supplied at the end of experiment, to restore level - - - - - - - -	0.0	949.0
19	Deduction for temperature of water supplied at end of experiment, in pounds - - - - - -	0.0	141.0
20	Pounds of water evaporated per hour, during steady action -	683.56	556.994
21	Cubic feet of water per hour, during steady action - -	10.93	8.896
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - - -	1.810	1.475
23	Pounds of water per square foot, by a mean of several observations - - - - - - - -	1.846	1.494
24	Water evaporated by 1 of coal, from initial temperature (a) final result - - - - - - -	7.7627	7.3524
25	Water evaporated by 1 of coal, from initial temperature (b) during steady action - - - - - -	7.309	6.424
26	Pounds of fuel evaporating one cubic foot of water - -	8.0513	8.5007
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - - - -	52°.06	55°.07
28	Mean temperature of wet bulb thermometer, during steady pressure - - - - - - - -	43°.81	48°.21
29	Mean temperature of air, on arriving at the grate - -	220°.31	201°.21
30	Mean temperature of gases, when arriving at the chimney -	276°.75	275°.36
31	Mean temperature of steam in the boiler - - -	234°.12	233°.21
32	Mean temperature of attached thermometer - -	48°.41	52°.46
33	Mean height of barometer, in inches - - -	30.382	30.277
34	Mean number of volumes of air in manometer - -	4.96	5.038
35	Mean height of mercury in manometer - - -	.562	.5536
36	Mean height of water in syphon draught gauge, in inches -	.3714	.3373
37	Mean temperature of dew point, by calculation - -	28°.31	38°.70
38	Mean gain of temperature by the air, before reaching grate -	168°.25	146°.14
39	Mean difference between steam and escaping gases - -	44°.46	45°.18
40	Water to 1 of coal, corrected for temp. of water in cistern -	7.7627	7.3524
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - - -	8.9761	8.5068
42	Pounds of water, from 212°, to one cubic foot of coal -	515.38	452.50
43	Water, from 212°, to one pound of combustible matter of the fuel - - - - - - - -	9.6476	9.2288
44	Mean pressure, in atmospheres, above a vacuum - -	1.4345	1.4298
45	Mean pressure, in pounds per square inch, above atmosphere	6.4174	6.3447
46	Condition of the air plates, at the furnace bridge - -	Closed.	Open.
47	Inches opening of damper, (U. upper, L. lower) - -	U. 8	U. 8

TABLES XXIII, XXIV, XXV, XXVI.
high anthracite coal.

3d Trial. (Table XXV.)	4th Trial. (Table XXVI.)	Averages.	Remarks.
Nov. 2.	*Nov.* 3.		
23.833	25.0		
3.716	5.133		
14.07	16.25		
277.5	377.5		
18.75	21.65		
8.0	10.0		
875.5	1116.5		
848.0	1083.25		
27.5	33.25	36.125	The unburnt coal at the second trial is 49.25, and the mean of the other three trials is 31.75 lbs.
54.715	55.825	55.2843	
91.698	112.45	101.521	
6.517	6.92	6.9475	
6.573	7.559	7.2235	
0.7929	1.128	1.079	
12.0621	14.922	14.965	
6803.0	8473.0		
51°.7	51°.6		
0.0	418.0		
0.0	63.0		
711.51	958.4	727.616	
11.38	15.33	11.634	With the air plate open, in the second trial, 8.9 cubic feet of water per hour only were evaporated; with the same plate closed, in the first trial, 10.9 cubic feet were evaporated.
1.885	2.538	1.927	
2.364	2.513		
8.0224	7.768	7.7264	
7.788	8.010	7.383	
7.7907	8.0456	8.1971	
60°.86	54°.93		
53°.0	46°.43		
237°.28	–	219°.6	No observations on the fourth trial.
297°.64	309°.5	287°.312	
232°.71	234°.86		
56°.64	49°.64		
29.933	30.14		
5.044	4.757		
.553	.5821		
.3437	.4458	.3755	
45°.01	33°.02		
176°.42	–	163°.603	On the fourth trial the derangement of thermometer prevented observations.
61°.375	77°.4	57°.004	
8.0224	7.768	7.7264	
9.2686	8.9747	8.932	
507.13	501.01	494.095	
9.9207	9.7086	9.6264	The evaporative effect in the second trial, when the air plate was open, was inferior to either of those made with the same plate closed.
1.4247	1.4941	1.4458	
6.2730	7.2970	6.5830	
Closed.	Removed.		
U. 10	U. 10		

Remarks on the foregoing table of deductions.

Many circumstances appear to indicate that the Lehigh anthracite burns with considerable difficulty—owing, perhaps, in part, to the nature of its incombustible constituents. The length of time required to bring the boiler to steady action, the quantity of coal left unburnt after the fire had become extinct, and the moderate rate of evaporation, together with the low evaporative efficiency of the coal, and especially with the large quantity of oxygen found on the fourth trial in the gases escaping to the chimney, all tend to demonstrate the want of a vigorous and easy combustion. To these circumstances may be added the fact, that, when in the second trial the air plate at the furnace bridge was open, in order to give an increased supply of air to the products of combustion, the effect was to diminish, instead of increasing, the evaporative efficiency of the pound of coal. In the 41st line, it appears that with the air plate closed, as in the first, third, and fourth trials, the steam from water at 212° produced by 1 of coal, was, on an average, 9.073; while in the second, it was but 8.509; indicating a loss of more than 6.2 per cent. Nor is this difference attributable solely to the difference in amount of waste matter found after the several trials; for it will be observed in the 43d line, that when allowance was made for this circumstance, the water from 212° to 1 of *combustible matter*, was on the

First trial - - - - - - - -	9.6476
Third trial - - - - - - - -	9.9207
Fourth trial - - - - - - - -	9.7086
And the mean - - - - - - -	9.7589

While for the second it was 9.2288—the difference being still 5.4 per cent. of the larger number.

The very close approximation in the above numbers for the first and fourth trials was given notwithstanding the difference in the size of the grate in the two cases, its area having been 14.07 on the former, and 16.25 on the latter day of trial. The accordance was given also even with the wide disparity of draught in the chimney on the two days—the syphon having stood on the first at 0.3714, and on the fourth day's trial at 0.4458 inch. The superior force of draught is explained in the way already indicated, by a *remark* at the commencement of experiments in table XXVI, where it is stated that the weather was clear, and the wind brisk from the northwest. The two circumstances of a stronger draught and a larger grate surface occasioned the evaporation of 15.33 cubic feet of water per hour during the fourth trial; while only 10.93 cubic feet were expelled in the same time during the first experiment. By a reference to table CXCIV, it will be seen how large a portion of all the heat developed by this coal was expended on the gaseous products of combustion. That table will also afford the means of determining how nearly the total evaporative power of the Lehigh anthracite approaches to that of other coals of the same class, when all the absorbents of heat are brought into the computation.

No. 6.

Anthracite from the Lackawanna coal region, Luzerne county, Pennsylvania, forwarded by the Delaware and Hudson Canal Company.

No certificate of origin accompanied this sample of coal, but only a bill of lading, indicating by whom it had been sent. The quantity was exactly 4,480 lbs., or two gross tons, as certified in the bill of lading.

The characters of the coal are, in general, a deep jet-black color, except on the surfaces of superposition, on which the usual deposites of mineralized charcoal are seen, and occasionally in the natural partings, technically called "cleats," which appear to be formed by thin laminæ of the earthy ingredients of the coal: these appear to be, generally, sulphate of lime; sulphuret of iron is scarcely discernible on the surface. The fracture is uneven, and semi-conchoidal, except in the direction of the main cleat.

This coal undergoes no change by an exposure of twenty months to varying states of atmosphere. Its specific gravity, as determined by the mean of two separate trials, was found to be 1.4213; which would indicate that, in the solid state, as it exists in the mine, the weight of a cubic foot is 88.83 lbs. avoirdupois.

In the state of marketable lump coal, in which it came to hand, the weight, as determined by forty-four trials in the charge box, was 48.886 lbs. per cubic foot, or .5502 of the above calculated weight. This, together with the variableness of the charges, in regard to weight, will be understood by reference to the column headed "*weight of charges of coal.*" From the numbers there given, it will be seen that the highest weight of any one charge was 108 lbs., or 54 lbs. per cubic foot; and the lowest 90.5 lbs. per charge, or 45.25 lbs. per cubic foot; and that the mean of these two extremes differs in excess from the above general mean, only about three-quarters of a pound. From these facts, it appears that the space required in the bunkers of a steam ship for the stowage of one ton of 2,240 lbs. of this anthracite, is 45.82 cubic feet.

In analyzing this coal, the moisture expelled by a temperature of 216° was, in one case, 1.382, and in another 1.174 per cent.; or the mean was = 1.278 per cent. A heat of full ignition expelled in addition, from the same specimens, a mean of 5.087; showing the total volatile matter to be = 6.365 per cent.

Four trials on each specimen, by incinerating them in platinum capsules placed for some hours in the open muffle of an assay furnace, left of earthy matter for one specimen 4.84, and for the other 4.47 per cent.—mean, 4.655. The sum of the volatile and earthy ingredients deducted from the total weight, for ascertaining the combustible fixed carbon, gives 88.98. On one of the specimens above referred to, was made a trial to ascertain the proportion of sulphur; which resulted in giving 0.1226 of one per cent. On two other specimens of this coal, Dr. King made trials to determine the quantity of matter volatile at redness, which resulted in giving for one 6.05, and for the other 4.875 per cent., or a mean of 5.462.

While prosecuting the experiments on evaporation, 45.53 lbs. were placed in the steam drying apparatus, where it remained for about 48 hours, most of the time surrounded by steam a little above the temperature of 212°: during that time it lost 15.5 ounces, or 2.12 per cent. The coal

used in this trial had for some time previous been exposed to a temperature not exceeding 50° Fahrenheit, and the size of lumps was from three to four inches in diameter.

A trial of 18 grains of this coal intimately mixed with 800 grains of litharge, and covered with a portion of pure litharge, effected the reduction of 568.86 grains of lead, or 31.603 times the weight of coal used. This trial was made on a specimen of which the moisture and earthy matter had been found to be 5.656 per cent.; and consequently the quantity of matter truly *combustible*, by which the reduction was effected, was 16.982 grains: from which it appears that one part of the combustible matter of this coal reduced 33.49 parts of lead. And as it is known that one part of pure carbon is capable of reducing thirty-four parts of lead, it seems that the *reductive* or "*heating power*" of this combustible, as deduced from this test, differed from that of pure carbon by only 1-68th part.

The character of the residua of this coal, procured by analysis, is that of a dense white or slightly grayish ash, of which the per centage is given above.

From the column of "remarks" in the accompanying tables, the proportion of *waste* derived from actual combustion will be seen to vary in the different trials, from 7.276 to 10.694 per cent. The total amount of *ashes*, mixed of course with a certain proportion of fine particles of unburnt anthracite, such as passed the meshes of a sieve three-tenths of an inch in diameter, was 318.35 pounds; and that of the vitrified portion, or *clinker*, was 52.07 pounds; both derived from the combustion of 4112.51 pounds of anthracite. Hence it appears that the ashes are 7.741 per cent., and the clinker 1.266 per cent., of the coal actually burned in the manner described in the tables. The ashes weighed 50.95 pounds per cubic foot, the clinker 36.88 pounds. Five pounds of soot and dust from the flues, left 3.264 pounds after complete incineration.

The clinker is very imperfectly vitrified, agglutinating, and often covering portions of nearly pure white argillaceous matter.

In order to ascertain what proportion of the ashes was really combustible, a quantity was reduced to fine powder, and a weighed portion exposed on a platinum capsule, in an open muffle, to a bright red heat for several hours, occasionally agitating it to expose every part to the access of air: the result was, that 34.555 per cent. of the whole was combustible; or of the 7.741 per cent. of ashes, 5.066 only were actually incombustible. The ashes thus finally obtained were of a nearly chocolate brown, showing that the specimens above analyzed did not properly represent the general mass of this anthracite, in regard to the color of its ashes.

Having reduced a portion of the clinker also to very fine powder, it was in like manner exposed for some hours to bright ignition, to ascertain whether any portions of anthracite had been retained in the interior of its mass, and had thus escaped combustion. The result was an actual gain, instead of a loss of weight. This gain, amounting to 0.55 of one per cent. of the substance tried, was doubtless due to a conversion of some portion of protoxide into peroxide of iron, the powder having been observed to be partially magnetic before calcination, but not so afterwards.

In the ashes and clinker above reduced, there were contained for the four trials of this coal, 2.647 pounds of wood ashes, derived from the wood employed in raising temperature. This amounts to almost exactly one per

cent. of the total waste, after deducting the unburnt anthracite of the ashes, as above stated. Hence the analysis of about 4,100 pounds of Lackawanna anthracite yielded 6.346 per cent. of incombustible matter, of a reddish-brown color, instead of 4.655 per cent. of a white or grayish-white ash, as afforded by the analysis above presented. The difference in color is accounted for by the known fact that the sulphuret of iron, which is the cause of redness, is often very irregularly distributed through the mass of a coal bed, and its accompanying slates. Specimens may chance to be selected for analysis which are almost wholly free from that ingredient.

The time required for bringing the boiler to steady action by this coal was, in the several trials, 0.75, 4.5, 2.5, and 2.91 hours; or, on an average, 2.666 hours. The quantity of anthracite left upon the grate was, by a mean of the four trials, 57.19 pounds. The use of this coal in a grate for domestic purposes, will be but little different from the mean action of red ash coals in general. The considerable quantity of water it contains causes it, when suddenly thrown on a mass of highly ignited coal, to decrepitate with considerable force; but in this it was not observed to surpass several other samples of the same class. It corresponds well in this particular with the Lackawanna anthracite used by many of the steamers on the New York waters, which I have observed, while driven with a strong artificial blast, to emit copious showers of fine particles from the chimney tops, speedily covering the deck and all other objects on which they could rest. A more moderate draught would avoid this inconvenience and loss, but would demand a considerable increase of furnace room to effect the requisite amount of combustion, and supply the necessary quantity of steam.

Being among the earliest in the series of experiments, the first and second trials will be found to lack the observations on the wet bulb thermometer, and those of the attached thermometer.

TABLE XXVIII.—LACK

First trial—upper damper 12

Period of steady action from 11*h*. a. m. to 3*h*. 45*m*. p. m. =4*h*. 45*m*.; coal supplied, 481.75 lbs.; water, 2,627 lbs.; 10 sets of observations.

Period of nearly steady *pressure*, as indicated by the dotted lines, from 10*h*. 15*m*. a. m. to 4*h*. 30*m*. p. m.

AWANNA ANTHRACITE.

inches open; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 40.94 feet.
h. m.					
-	-	111	—28	-	Commenced firing at 8*h*. 50*m*. a m.
-	-	93	+48	-	Wood consumed, 203¾ lbs.
10.15	-	93.5	35	-	First charge of coal in; steam begins to blow off.
10.30	-	100.5	70		
11.00	-	106	64	1.478	
-	-	121	54	1.287	
11.40	-	137.5	57	1.350	
-	-	156.5	56	1.374	
0.25	-	174	51.5	2.110	
-	-	201.8	58	0.873	
1.25	-	213	32	1.801	
-	-	222	36	1.545	
3.00	-	235	32	1.576	
-	-	241	26	1.350	
3.45	-	246	36	1.112	
-	-	239	87	1.925	
-	-	239	91	2.649	Filled tank.
-	-	244	88	1.751	At 7*h*. 30*m*. p. m. supplied 555 lbs. more (making to that time 5,806 lbs.) of water to boiler.
-	-	100	—29	-	Water adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	8.375
Ashes - - - - - - - - - -	58.00
	66.375
Deduct wood ashes - - - - - - - - -	0.625
Total waste from coal - - - - - - - -	65.750
Coke - - - - - - - - - -	38.25

TABLE XXIX.—LACK

Second trial—upper damper 12 *inches open; air plates removed;*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of charges of coal.
	h. m. A. M.													
April 11	5.50	40	-	80	100	47.5	125	-	30.05	-	-	0.10	-	-
	8.00	44.5	-	117	158	47.5	128	-	30.10	-	-	0.17	-	-
	9.10	47.5	-	148	238	47.5	225	-	30.11	0.185	8.74	0.17	-	90.12 38.25
	9.30	48	-	148	242	48	222	-	30.12	0.189	8.70	0.20	178	93.00
	10.20	50	-	170	244	47	225	-	30.12	0.190	8.69	0.20	348	93.50
	10.55	50.5	-	206	254	46.5	228	-	30.11	0.186	8.72	0.20	528	-
	11.35	51	-	234	234	46	228	-	30.10	0.183	8.76	0.18	956	97.75
	P. M.													
	0.00	51.5	-	260	250	46	229	-	30.10	0.196	8.62	0.20	1363	-
	1.15	52.5	-	260	242	46	230	-	30.07	0.193	8.66	0.20	1943	97.00
	2.00	54	-	-	246	52.5	229	-	30.07	0.190	8.69	0.23	2350	-
	2.40	54.5	-	-	244	52	230	-	30.06	0.186	8.72	0.25	2768	-
	3.20	57	-	282	278	53	230	-	30.04	0.196	8.62	0.28	3108	95.00
	4.00	57	-	294	274	53	230	-	30.04	0.193	8.66	0.27	3698	-
	4.30	58	-	300	284	54	230	-	30.04	0.197	8.61	0.27	4213	90.50
	5.15	58	-	320	284	52	229	-	30.03	0.193	8.66	0.28	4898	95.00
	5.45	58	-	310	290	51	228	-	30.02	0.197	8.61	0.27	5353	-
	6.00	57.5	-	330	296	50	230	-	30.02	0.199	8.60	0.28	5473	97.00
	6.30	57	-	380	236	51	224	-	30.02	0.166	8.94	0.25	6423	-
	A. M.													
April 12	7.20	48	-	174	160	52	199	-	30.04	-	-	0.12	8633	-

Period of steady action from 2*h.* p. m. to 6*h.* p. m. = 4*h.*; coal supplied in that time, 386.5 lbs.; water, 3,120 lbs.; 7 sets of observations taken.

AWANNA ANTHRACITE.

grate raised to within seven inches of the bottom of the boiler.

			Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 40.77 feet.
h. m.	-				
-	-	40	—25	-	Water in boiler 0.4 inch below normal level; commenced firing at 5*h.* 10*m.* a. m.
-	-	72.5	—24		
9.10	-	100.5	+13	-	Wood consumed, 462 pounds; after first charge, threw in coke remaining from first trial.
9.30	-	100	20	1.415	Placed 45 lbs. 8½ oz. of this coal in drying apparatus. It weighed, (April 12,) after 24 hours drying, 45 lbs.
10.20	-	120	19	0.540	
-	-	155.5	26	1.271	
11.35	-	182	6	1.311	
-	-	208.5	21	1.170	
1.15	-	207.5	12	2.048	Filled tank. Thermometer for air entering back of grate broken, and a new one substituted.
-	-	-	17	1.446	
-	-	-	14	1.647	
3.20	-	225	46	1.351	
-	-	237	[illegible]	2.344	
4.30	-	242	64	2.728	
5.15	-	262	55	2.419	
-	-	252	62	2.411	Filled tank at 5*h.* 55*m.* p. m.
[illegible]	-	272.5	66	1.271	
-	-	[illegible]	12		
-	-	126	—39	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	9.69
Ashes - - - - - - - - - - -	60.25
Total clinker and ashes - - - - - - - -	69.94
Deduct wood ashes - - - - - - - - -	1.418
Total waste from coal - - - - - - - -	68.522
Coke - - - - - - - - - - -	50.51

TABLE XXX.—LACK

Third trial—upper damper 10 *inches open ; air plates closed ;*

The period of steady action this day extends from 9*h*. 5*m*. a. m., when the fifth charge was all on the grate, to 4*h*. 45*m*. p. m., when the thirteenth and last charge was on, — 7*h*. 40*m*.; coal supplied, 799.5 lbs.; water, 7,226 lbs.; sets of observations taken, 15. By these data, the water to 1 of coal is 9.088, whilst the final result (as seen in the table of deductions) is 8.567. The excess of the former over the latter number, is probably attributable to the large amount of coal put on the grate in the early part of the experiment, before the period of steady action commenced, and which doubtless exceeded the quantity on the grate at the time the period of steady action terminated. Such differences must inevitably occur, since the eye only can be relied on to judge of the quantity remaining unburnt at any given moment.

...AWANNA ANTHRACITE.

...steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between the steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					First charge thrown on grate behind wood.
5.25	64.9	58	-	-	Water at normal level, wind NE.; raining; commenced charging.
6.35	65.4	54	+ 4	-	Consumed 137.25 lbs. of wood; steam blowing off.
7.00	66.2	73.5	18	1.215	
7.45	66.0	101	40	1.979	
-	67.0	130	34	1.657	Filled tank at 9*h.* 10*m.* a. m.
9.05	68.0	143	30	2.569	
10.00	70.0	168	29	2.225	
-	69.7	186	25	1.812	
10.45	69.3	199	24	2.638	
11.30	69.3	213	26	2.146	
-	69.3	221	46	2.728	
-	69.3	223	54	2.728	
0.40	69.3	235	40	3.019	
1.30	70.1	233	40	2.702	
2.20	69.7	266	35	2.728	Filled tank at 2*h.* 40*m.* p. m.
-	70.3	270	40	3.179	Commenced drawing gases at 3*h.* 3*m.* p. m.; drew in 25 minutes 101 cubic inches, which gave 0.02 grain water, and 4.03 grains carbonic acid.
-	69.3	271	-	2.199	
4.00	69.3	281	31	2.649	
-	68.9	284	26	1.812	
4.45	68.9	296	14	1.377	
-	70.3	294	16	1.833	Valves double weighted; contents of ash pit thrown on grate.
-	69.9	298	— 3	-	Water brought to 2.1 inches above normal level; valves unloaded; filled tank; damper reduced to 5 inches; water at 10*h.* p. m. brought 0.2 inch above normal level; damper set at 3 inches.
-	67.1	211	—17		
-	67.7	145.5	-	-	Water in boiler 0.05 inch below normal level.
-	65.4	144	-	-	Water adjusted.

RESIDUA.

	Pounds.
Clinker	22.75
Ashes	85.50
Ashes from behind bridge	3.00
Total clinker and ashes	111.25
Deduct wood ashes	0.411
Total waste from coal	110.839
Coke	54.

TABLE XXXI.—LACK

Fourth trial—upper damper 5 inches open; air plates half open;

Period of steady action from 9*h*. 15*m*. a. m. to 6*h*. 10*m*. p. m.—8*h*. 55*m*.; coal supplied during that period, 776 lbs.; water, 6,279.5 lbs.; 18 acts of observations taken; water to 1 of coal, 8.071. The final result being 8.586, shows that there was more coal on the grate at the end than at the beginning of the period assumed as that of steady action.

AWANNA ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
5.50	65.4	144	-	-	Commenced firing; water in boiler 0.2 inch above normal level.
6.20	66.0	123	—58	-	Wood consumed, 63 lbs; commenced charging with coal; placed double weights on safety valves; removed second weight from safety valve at 6*h*. 45*m*., which allowed the steam to blow off, none having previously escaped. Steady pressure from 8*h*. 0*m*. a. m. to 6*h*. 30*m*. p. m.
6.45	65.5	117	—54		
-	66.6	112	+13	0.751	
7.50	66.0	116	23	0.937	
-	65.5	121	22	0.901	
-	65.5	131	32	1.351	
9.15	65.1	142	32	1.836	
-	64.8	153.5	29	2.177	A charge of this coal, egg size, weighed 102.25 lbs.
-	66.2	167	31	1.335	
11.00	65.8	178	28	2.511	
-	65.3	183	25	2.278	
0.00	66.5	190	26	1.807	
-	66.9	195	26	1.398	Partly filled tank; wind W.; morning has been cloudy, now sun shining occasionally.
-	66.1	195	21	0.636	
1.00	67.6	203	38	2.681	
-	67.2	200	48	1.701	
2.25	66.5	209	39	1.271	
-	68.1	214	43	2.252	A charge of this coal, egg size, weighed 102.75 lbs.
3.10	69.2	225	27	2.172	
-	70.4	241	30	1.351	
4.15	70.0	241	33	2.225	Commenced drawing gases at 4*h*. 35*m*. from lower flue; drew in 15 minutes 100 cubic inches, which gave water 0.69 grain, carbonic acid 5.36 grains, and oxygen 12.12 cubic inches.
-	71.2	234	30	2.252	
5.15	70.9	251	42	1.669	
-	71.7	265	29	1.859	
6.10	74.1	282	22	1.256	Air plates closed; contents of ash pit thrown on grate at 6*h*. 30*m*.; valves double weighted.
-	73.8	203	8	-	Water brought to 1.9 inch above normal level; wind SE., clear; valves unloaded at 7*h*. 20*m*. p. m.
-	70.0	155	—10	-	Water not visible in gauge.
-	71.2	142	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	11.25
Ashes - - - - - - - - - - -	111.50
Ashes behind bridge - - - - - - - - - -	2.75
	125.50
Deduct wood ashes - - - - - - - - - -	0.193
Total waste from coal - - - - - - - - -	125.307
Coke - - - - - - - - - - -	85.25
Soot - - - - - - - - - - - -	2.50

TABLE XXXII.—DEDUCTIONS FROM

Experiments on Lacka

	Nature of the data furnished by the respective tables.	1st Trial. Table XXVIII.	2d Trial. Table XXIX.
		April 8.	*April* 11.
1	Total duration of the experiment, in hours	21.916	25.5
2	Duration of steady action, in hours	4.75	4.0
3	Area of grate, in square feet	16.25	16.25
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.65	21.65
6	Number of charges of coal supplied to grate	8.0	10.0
7	Total weight of coal supplied to grate, in pounds	768.25	992.25
8	Pounds of coal actually consumed	730.0	941.74
9	Pounds of coal withdrawn and separated after trial	38.25	50.5
10	Mean weight, in pounds, of one cubic foot of coal	48.015	47.7
11	Pounds of coal supplied per hour, during steady action	101.401	96.625
12	Pounds of coal per square foot of grate surface, per hour	6.24	5.946
13	Total waste, ashes and clinker, from 100 pounds of coal	9.007	7.276
14	Pounds of clinker alone, from 100 pounds of coal	1.136	1.028
15	Ratio of clinker to the total waste, per cent.	12.617	13.85
16	Total pounds of water supplied to the boiler	6220.0	8633.0
17	Mean temperature of water, in degrees Fahrenheit	48°.07	50°.7
18	Pounds of water supplied at the end of experiment, to restore level	914.0	2210.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	136.0	330.0
20	Pounds of water evaporated per hour, during steady action	553.05	780.0
21	Cubic feet of water per hour, during steady action	8.848	12.48
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.491	2.029
23	Pounds of water per square foot, by a mean of several observations	1.437	2.024
24	Water evaporated by 1 of coal, from initial temp. (a) final result	8.3342	8.8166
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	5.453	8.125
26	Pounds of fuel evaporating one cubic foot of water	7.335	7.089
27	Mean temperature of air entering below ash pit, during steady pressure	56°.09	54°.96
28	Mean temp. of wet bulb thermometer, during steady pressure	—	—
29	Mean temperature of air, on arriving at the grate	241°.0	278°.6
30	Mean temperature of gases, when arriving at the chimney	279°.08	264°.67
31	Mean temperature of steam in the boiler	228°.35	229°.25
32	Mean temperature of attached thermometer	—	—
33	Mean height of barometer, in inches	29.573	30.058
34	Mean number of volumes of air in manometer	8.819	8.661
35	Mean height of mercury in manometer	.1777	.1924
36	Mean height of water in syphon draught gauge, in inches	.233	.2714
37	Mean temperature of dew point, by calculation	—	—
38	Mean gain of temperature by the air, before reaching grate	184°.1	213°.64
39	Mean difference between steam and escaping gases	43°.85	49°.0
40	Water to 1 of coal, corrected for temperature of water in cistern	8.3342	8.8166
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.6531	10.1945
42	Pounds of water, from 212°, to 1 cubic foot of coal	463.49	486.29
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.6086	10.9948
44	Mean pressure, in atmospheres, above a vacuum	1.3936	1.426
45	Mean pressure, in pounds per square inch, above atmosphere	5.8124	6.2918
46	Condition of the air plates at the furnace bridge	Removed.	Removed.
47	Inches opening of damper, (U. upper, L. lower)	U. 12	U. 12

TABLES XXVIII, XXIX, XXX, XXXI.

wanna anthracite coal.

3d Trial. Table XXX.	4th Trial. Table XXXI.	Averages.	Remarks.
July 13.	*July* 14.		
24.33	26.25		
7.66	8.916		
14.07	14.07		
377.5	377.5		
18.75	18.75		
13.0	13.0		
1323.0	1257.0	–	In the second trial, 38.25 lbs. of anthracite, left from the preceding day's work, were added to the ten charges, to make up the 992.25 lbs. supplied to the grate.
1269.0	1171.95		
54.0	85.75	59 62	The upper damper drawn but five inches, and the air plates half open, in the fourth trial, appear to have materially influenced the amount of coal left unburnt on the grate; the mean of three trials, under other circumstances, having given but 47.58, while the fourth trial gave 85.75 lbs.
50.884	48.346	48.736	
104.39	87.259	97.394	
7.413	6.203	6.45	
8.734	10.694	8.9277	
1.842	0.9586	1.2411	
21.016	8.964	14.1117	
10997.0	10348.0		
78°.7	77°.7		
110.0	2172.0		
14.0	282.0		
942.6	704.297	744.987	
15.08	11.268	11.919	
2.497	1.867	1.971	
2.484	1.857		
8.576	8.5863	8.5783	
9.038	8.071	7.6717	The numbers in this line are, of course, as in all other cases, but approximations, dependent on the quantity of coal actually on the grate at the beginning and end of the assumed period of steady action.
7.352	7.28	7.264	
73°.58	79°.83		
70°.28	71°.33		
284°.67	280°.81	271°.27	
263°.88	266°.86	268°.62	
231°.44	231°.0		
72°.66	76°.85	–	The observations of the attached thermometer were not commenced until after the first two trials of this sample had been completed.
30.29	30.263		
5.042	5.145		
.5535	.5477		
.3353	.2955	.2838	
68°.86	67°.84	–	The observations for dew point were not made during the first two trials. The gas-drawing apparatus had not then been completed, with a view to which the *dew point* was more particularly desirable.
211°.09	200°.98	202°.45	
32°.85	31°.5	39°.30	
8.551	8.5567	8.5646	
9.6976	9.6099	9.7888	
493 41	467.5	477.67	
10.6346	10.8278	10.7639	
1.4518	1.4296	1.4252	
6.6719	6.3447	6.2802	
Closed.	Half open.		
U. 10	U. 5		

General remarks on the preceding table of deductions.

It appears that with a chimney 41 feet in height, as in the first and second trials of Lackawanna coal, and with the damper drawn so as to give free exit to the gases as rapidly as they would pass the two interior 10-inch flues, the rate of evaporation was from 8.85 to 12.48 cubic feet of water per hour. After the chimney had been raised to 63 feet in height, the rate of evaporation on the third trial, when the damper was drawn 10 inches, was 15.08 cubic feet per hour; and on the fourth, when it was opened but 5 inches, the rate was 11.27 cubic feet. Notwithstanding these considerable differences in the rate of evaporation, with variations also, as seen in the third line of the table, in the area of the grate, and in the opening, closing, or removal of the air plate at the furnace bridge, as given in the 46th line, the accordance in the results of the four trials found in the 40th, 41st, and 43d lines, is as near as could reasonably be expected from the operations of combustion. In the second experiment the grate was placed within 7 inches of the bottom of the boiler, and the result of that trial is about two per cent. higher than the general average, as shown in the 43d line. That was, however, found too near for convenient management, and the distance of 9 inches was resumed after one or two trials. It is important that the fireman should be able to observe, especially in burning anthracite, that all parts of his grate are uniformly well covered with fuel. If large holes are allowed to exist in some parts, while heavy accumulations of coal remain on others, both may become sources of loss; the one by allowing unburnt air to pass, and the other by forming carbonic oxide, which may in part escape subsequent combustion.

In the table (CXCIV) of experiments on the composition of gases from combustion will be found some indications of the differences which exist in the action of a furnace while using the same kind of fuel. It will also be perceived that on the fourth trial of Lackawanna coal, the heat employed on the air required for the combustion of a pound of coal was equal, in evaporative power, to convert about nine-tenths of a pound of water at 212° into steam of the same temperature. With respect to the anthracites generally, it may be said that their combustion is effected solely by the *contact* of air with the surfaces of their solid masses. In the case of bituminous coals, on the contrary, the air which supplies combustion is inevitably intermixed, during its passage through the fire, with much fuel in a gaseous state. The existence, therefore, in an anthracite fire, of passages or "blow holes," through which considerable currents of air can pass without bringing every atom of it in contact with a lump of fuel, is an almost sure source of loss of useful effect. In the bituminous coal fire, the want of such openness, to allow sufficient air to effect the complete combustion of the gaseous products, has given rise to the many inventions for preventing smoke, and burning more completely the gaseous products of the fuel.

No. 7.

Anthracite from Lykens valley, Dauphin county, Pennsylvania, sent by the Lykens Valley Coal Company.

This sample of coal was accompanied by the following letter to the President of the late Board of Navy Commissioners:

"BALTIMORE, *July* 23, 1842.

"DEAR SIR: At the request of the Lykens Valley Coal Company, we forward to you for trial three hogsheads of coal from their mines. It is from vein No. 1, seven feet thick, and has been mined four weeks; can be delivered at any point on the Atlantic coast, from the Chesapeake bay, which it reaches through the Pennsylvania and Tide-water canals. You will please communicate the result of your trial of it to us.

"Your obedient servants,

"J. WHITEFORD & CO.

"Commodore WARRINGTON."

The exterior characters of this anthracite are very nearly related to those of many bituminous coals. Its fracture is uneven and splintery, except where the main cleats or partings are exposed. It differs from most of the anthracites already described, in the circumstance of having the surfaces of deposition often exposed in the fractures, displaying copious deposites of carbonaceous "clod," or mineralized charcoal, preserving the vegetable forms from which it was derived. In these and many other characteristics, it strongly resembles many samples of the anthracite of South Wales, which have fallen under my notice.

Two specimens were tried for specific gravity: the first gave 1.3828, and the second 1.3954. The mean weight per cubic foot of solid coal in the mine will hence be 86.82 pounds.

Twenty-six trials in the charge box gave the mean weight per cubic foot, in the state in which it was received, 48.558 pounds—showing that the *actual* is 0.5591 of the *calculated* weight. This proves that the space required for stowing one gross ton is 46.13 cubic feet. The greatest weight in any charge was 106, and the least 91 pounds—the mean of which gives 49 pounds per cubic foot.

Two boxes of this coal were reduced to egg size; in which state one weighed 93½, and the other 96 pounds—showing the average weight per cubic foot to be 47.375 pounds, or 1⅕ pound less than the average weight above stated.

The moisture expelled in analyzing the two specimens above mentioned was 0.707 and 0.785, respectively; and the portion expelled from 28 pounds placed in the drying apparatus of the boiler was only half an ounce, or 0.111 per cent.

On exposure to a bright red heat in a closed platinum crucible, the first specimen lost, in addition to its moisture, 6.263; and the second 5.874 per cent.—showing that the mean amount of volatile matter is 6.314. Two specimens tried by Dr. King yielded a mean of exactly 7 per cent. of volatile matter, including moisture.

The proportion of sulphur found in the first of the above specimens is

0.091 of 1 per cent—a quantity which can certainly be of little consequence to the character of the coal.

Analyses of the two specimens above mentioned gave of earthy matter 5.4 and 5.66 per cent. of the weight of raw coal.

This gives the composition as follows, viz:

Volatile matter - - - - - -	6.814
Earthy matter - - - - - -	5.530
Fixed carbon - - - - - -	87.656
	100.

The ashes obtained from these analyses are of a fawn color, slightly coherent, bulky, and but moderately gritty, resembling fine clay.

From the accompanying tables of experiments, it will be found that there were consumed in the three trials of this anthracite 2,471 pounds; from which were derived of ashes 189.798, and of clinker 109.75; or the total amount was 299.548 pounds. Hence the per centage of *waste* is 12.123.

lers are mostly reddish brown, with yellowish-white portions, s, even in the parts where the vitrification is most perfect. e slaty fragments have undergone no fusion. The ashes are ,y, and weigh 52.06 pounds per cubic foot; while the clinker 32.75 pounds.

es contained 36.8 per cent. of unburnt anthracite, and the 9 per cent. Hence the true amount of *earthy matter* in the 39.798—69.845 = 119.953 pounds; and that in the clinker is 745 = 108.005 pounds. There were obtained of soot and dust from the flues, after three days' burning of this coal, 1¾ pound; of which, the density was such, that 21.56 pounds would have been required to make 1 cubic foot; and of this mixture, experiment proved that 37.6 per cent., or 0.657 of a pound, was earthy matter, almost identical in characters with that of the ashes. From all these sources, we get the proportion of earthy matter from this coal equal to $\frac{119.953+108.005+.657}{2471}$ = 9.252 per cent., instead of 5.53, as given by the above analyses. It also appears that 12.123—9.252 = 2.871 per cent. of the coal escaped combustion and separation by the sieve.

In no instance was it found necessary to lay a charge of this anthracite upon the grate, in order to secure a speedy ignition after the wood was withdrawn. The mean time required to bring the furnace to steady action was 2.127 hours; only three-fifths as long as the average time required by the Lehigh, Beaver Meadow No. 3, Forest Improvement, and Peach Mountain anthracites.

The average amount of unburnt anthracite withdrawn after each trial was but 18 pounds; while the mean amount for the four samples just named was 53.83 pounds, or almost exactly three times as much. Both these circumstances indicate the approximation of the Lykens valley anthracite to the class of free-burning bituminous coals.

The first specimen above analyzed, when tested by oxide of lead, yielded 31.155 times its own weight of metallic lead. Deducting the moisture

and earthy ingredients, 0.707 + 5.40 = 6.107 per cent., we have the remaining or combustible portion = 93.893 per cent.; hence $\frac{100 \times 31.155}{93.893}$ = 33.181 = the reductive power of the combustible constituents of this coal.

In an open grate, this anthracite gives a quick, lively, and cheerful fire; but lacks the durability of several other samples. The proportion of fused cinder, or clinker, to the total waste being 37.5 per cent., it will not answer well for use in close stoves, heating furnaces and other apparatus, in which entire freedom from all tendency to produce slag and to clog the grate, is a property so much desired.

In blacksmiths' forges, cupolas, and smelting furnaces, it must doubtless be found to work easily, yielding an intense and rapid fire. For reasons already stated, no trials of it were made in the smith shops.

This coal breaks easily into small sizes; burns very freely, with considerable flame, but without any characteristic appearances of caking coals, and preserves the definite forms of its masses, except when it disintegrates during ignition into small angular fragments.

Its action under the steam boiler was highly satisfactory. Its considerable portion of volatile matter, which burns with a clear yellow flame, of moderate length and brilliancy, without the slightest appearance of smoke, and without requiring a very powerful draught to sustain and quicken the combustion, gives it a decided advantage for avoiding that waste which arises from a violent artificial blast.

TABLE XXXIII.—LYKENS

First trial—upper damper 8 inches open; air

	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
.33	5.22	0.15	–	–
.27	5.28	0.12	–	–
.20	5.36	0 21	–	92.25
.38	5.28	[illegible]	–	92.75
.30	5.27	0.27	[illegible]	92.00
.50	5.07	0.33	338	94.75
.53	5.04	0.35	660	–
.45	5.12	0.30	[illegible]	96.00
.41	5.16	[illegible]	[illegible]	93.50
.41	5.16	0 30	2087	–
.39	5.18	0.30	[illegible]	104.00
.43	5.14	0.30	2793	–
.42	5.15	0.28	3309	106.00
.40	5 17	0.28	3623	–
.40	5 17	0.28	4133	97.00
.32	5.25	0.26	4596	–
.31	5 26	0.25	5108	–
.84	5.72	0.20	[illegible]	–
.50	7.06	0.11	6608	–
.58	7.02	0.11	6982	–

The period of steady action this day is from 6*h*. 40*m*. a. m. to 11*h*. 5*m*. a. m. =4*h*. 25 *m*.; coal supplied to grate, 496.5 lbs.; water to boiler, 3,695 lbs.

VALLEY ANTHRACITE.

plates closed, and steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	50.3	160	-	-	Water in boiler brought to 0.2 inch above normal level.
-	52.8	121	—40	-	Commenced firing.
5.20	52.8	110	— 2	-	Wood consumed, 50.75 lbs.; commenced charging with coal.
5.33	50.7	109	—12	-	Coal ignites readily for anthracite; steam begins to blow off.
6.00	52.2	109	+14	0.930	Fire brisk; flame whitish; coal falls into fine fragments.
6.40	53.7	112	32	0.901	Both valves single weighted.
-	53.0	123	43	1.759	Placed 28 lbs. of this coal in drying apparatus.
7.30	58.1	142	36	2.299	
8.00	59.5	171	38	2.691	
-	62.1	191	23	2.305	Clear and calm weather.
8.55	61.6	212	28	1.806	
-	61.5	226	16	2.199	Wind NE., light.
10.00	53.7	235	16	2.172	
-	55.2	242	16	2.225	
11.05	51.1	262	12	2.316	Filled tank at 11*h.* 35*m.* a. m.
-	54.2	262	14	1.848	Contents of ash pit thrown on grate; broke wet bulb thermometer; damper reduced to 4 inches.
-	-	274	10	1.901	
-	-	246	0	-	Damper reduced to 3 inches; water left at 0.3 inch above normal level.
-	-	131	—22	-	Water 0.7 inch below normal level.
-	-	128	—21	-	Water in boiler adjusted; water supplied to restore level, 379 lbs.

RESIDUA.

	Pounds.
Clinker	41.50
Ashes	43.25
Ashes behind bridge	1.57
Total clinker and ashes	86.32
Deduct wood ashes	0.156
Total waste from coal	86.164
Coke	8.75

TABLE XXXIV.—LYKENS

Second trial—upper damper 8 inches open; air plates 6 rows open;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
July 24	4.18	78	70	148	174	77	186	77	29.96	0.349	7.06	0.08	-	-
	5.00	77.5	69.5	144	210	77	200	76	29.94	0.366	6.89	0.21	-	-
	6.15	78	70	145	226	77	229	76	29.93	0.521	5.36	0.22	-	96.75
	6.30	78	70	147	216	78	232	77	29.94	0.536	5.20	0.27	-	105.25
	7.00	78	70	154	268	78	230	78	29.94	0.583	5.24	0.29	172	92.50
	7.35	79	70	174	272	78	232	79	29.94	0.535	5.22	0.32	487	96.25
	8.00	80	71	184	280	78	233	79	29.94	0.543	5.14	0.33	832	-
	9.00	86	72	214	276	78	232	82	29.93	0.536	5.21	0.34	1722	94.00
	9.30	88	73	230	282	78	232	84	29.93	0.534	5.23	0.34	2132	-
	10.00	90	76	238	285	78	233	85	29.95	0.535	5.22	0.34	2547	95.50
	10.30	91	74	250	282	78	232	86	29.93	0.532	5.25	0.32	2967	98.20
	11.00	92	74	264	278	78	232	87	29.93	0.532	5.25	0.31	3399	-
	11.30	94	74	274	278	78	232	88	29.93	0.531	5.26	0.30	3822	-
	P. M.													
	0.00	95	75	282	276	78	232	88	29.93	0.530	5.27	0.30	4217	102.75
	0.30	96	75	286	276	79	232	89	29.93	0.522	5.35	0.30	4632	-
	1.10	96	76	298	268	78	232	89.5	29.92	0.522	5.35	0.26	5212	-
	2.30	97	75	298	276	86	232	91	29.91	0.517	5.40	0.25	6098	93.50
	2.50	94	74	304	260	86	230	91	29.91	0.515	5.42	0.25	6353	-
	3.45	96	74	308	248	86	232	91	29.91	0.525	5.32	0.25	6758	-
	4.00	96	75	302	244	86	230	91	29.91	0.521	5.36	0.25	7078	-
	4.45	96	81	298	240	86	231	91	29.91	0.507	5.50	0.20	7400	-
	A. M.													
July 25	5.30	74	68	178	192	86	215	78	30.03	0.366	6.88	0.20	7406	-
	5.45	74	68	176	191	86	210	77.5	30.03	0.350	7.05	0.18	7726	-

The period of steady action from 8*h.* 48*m.* a. m. to 1*h.* 55*m* p. m. is 5*h.* 7*m.*; coal supplied to grate, 390 lbs.; water to boiler, 4,168.37 lbs.

VALLEY ANTHRACITE.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	66.5	70	—12	-	Commenced firing; water at normal level at 200°; both valves loaded at 5*h.* a. m.
-	65.9	66.5	+10		
6.15	66.5	67	— 3	-	Wood consumed, 175.25 lbs.; wind NW., light; clear; water 0.35 inch above normal level.
6.30	66.5	69	—16	-	Front valve unloaded; steam blowing off.
7.00	66.5	76	+38	0.911	Damper set at 8 inches, and air plates opened.
7.35	66.1	95	40	1.430	A new wet bulb thermometer was this morning brought into use.
-	67.2	104	47	2 129	Filled tank at 8*h.* 40*m.*; wind W., light; clear.
8.48	66.6	128	44	2.384	
-	67.5	142	50	2.172	
10.00	71.5	148	52	2.198	A charge of this coal, egg size, weighed 93.5 lbs.
10.30	68.1	159	50	2.225	Both valves single weighted; steam escaping from both.
-	67.8	172	46	2.288	
-	67.2	180	46	2.241	Wind W., brisk; clear.
0.00	68.5	187	44	2.092	Eighth charge fine, with lumps.
-	68.2	190	44	2.198	
-	69.8	202	36	2.304	
1.55	67.9	201	44	1.760	Filled tank at 2*h.* 20*m.* p. m.
-	67.2	210	30	2.026	Air plates closed; contents of ash pit thrown on grate; damper reduced to 3 inches opening.
-	66.2	212	16	1.170	
-	68.2	206	14	-	Water 1 inch above normal level.
-	77.1	202	9	-	Water again brought to 1 inch above normal level.
-	65.1	104	—23		
-	65.1	102	—19	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	37.75
Ashes	60.75
Ashes behind bridge	1.57
Total clinker and ashes	100.07
Deduct wood ashes	0.538
Total waste from coal	99.532
Coke	16.50

TABLE XXXV.—LYKENS

Third trial—upper damper 4 inches; air

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
July 25	5.45	74	68	176	191	86	210	77.5	30.03	0.350	7.05	0.18	-	-
	6.35	79	69	182	233	85	226	79	30.07	0.510	5.47	0.24	-	99.75
	6.55	80	70	182	234	85	230	80	30.08	0.528	5.28	0.25	-	100.00
	7.55	81	69	180	240	85	228	82	30.09	0.527	5.30	0.28	87	-
	8.35	82	69	188	252	84	231	84	30.11	0.531	5.26	0.30	432	99.50
	9.05	83	68	196	258	84	232	84	30.11	0.540	5.17	0.30	772	-
	9.30	82	67	210	258	84	232	84	30.12	0.540	5.17	0.32	1094	91.00
	10.00	84	68	229	270	84	232	85	30.13	0.544	5.13	0.32	1514	94.00
	10.30	84	67	250	260	84	232	85	30.13	0.535	5.22	0.25	1927	-
	11.00	87	67	272	262	84	232	85	30.13	0.531	5.26	0.25	2477	95.75
	11.40	87	67	296	270	84	230	85	30.12	0.539	5.18	0.28	2909	-
	P. M. 0.10	89	70	324	260	82	228	84	30.12	0.517	5.40	0.25	3329	98.00
	0.40	89	70	344	248	82	230	84	30.12	0.534	5.23	0.25	3586	104.00
	1.30	88	69	340	268	84	230	84	30.12	0.536	5.20	0.30	4158	-
	2.10	90	71	340	252	84	228	84	30.11	0.517	5.40	0.22	4653	-
	2.40	88	69	330	262	84	230	84	30.11	0.532	5.25	0.30	4909	-
	4.20	86	69	304	244	84	230	84	30.11	0.524	5.33	0.21	5628	-
	5.00	86	68	294	240	84	228	84	30.10	0.514	5.43	0.22	5782	-
July 26	A. M. 6.00	74	68	190	206	84	218	77	30.21	0.410	6.46	0.13	5783	-
	6.30	75	70	188	204	84	214	77	30.21	0.366	6.89	0.13	6283	-

Period of "steady action" from 8*h.* 5*m.* a. m. to 0*h.* 45*m.* p. m. = 4*h.* 40*m.*; coal supplied to the grate, 482.5 lbs.; water to boiler, 3,470 lbs. The boiler had not probably quite reached its point of steady evaporation at the commencement of this period.

VALLEY ANTHRACITE.

plates closed; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet, length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	65.1	102	—19	-	Wind NE., light; clear; water at 0.1 inch above normal level; commenced firing.
6.35	64.5	103	+ 7	-	Wood consumed, 86½ lbs.; commenced charging with coal.
6.55	65.7	102	4	-	Removed second weight from valves; steam blows off; fire
-	65.3	99	12	0.230	moderately active; set upper damper at 4 inches.
8.05	63.2	106	21	1.371	
-	61.1	113	26	1.801	
9.15	59.8	128	26	2.046	Wind NE., brisk; clear; fire in small furnace extinguished,
9.57	60.7	145	38	2.225	and its damper closed.
-	59.0	166	28	2.188	A charge of this coal weighed, reduced to egg size, 96 lbs.
10.45	57.7	185	30	2.914	
-	57.7	209	40	1.717	Filled tank at m. to 3,030 pounds.
11.43	62.2	235	32	2.225	Coal in drying apparatus weighed 27 lbs. 15½ oz.
0.45	62.2	255	18	1.362	
-	60.9	252	38	1.818	Filled tank.
-	63.6	250	24	1.967	Contents of ash pit thrown on grate.
-	60.9	242	32	1.356	Fire rekindled in small furnace.
-	61.6	218	14	1.143	
-	59.9	208	12	-	Water in boiler left at 0.3 inch above normal level.
-	65.1	116	—12	-	Water 1 inch below normal level; damper at 4 inches during the night.
-	67.7	113	—10	-	Water adjusted.

RESIDUA.

	Pounds.
Clinker	30.50
Ashes	82.25
Ashes behind bridge	1.36
	114.11
Deduct wood ashes	0.262
Total waste from coal	113.848
Coke	28.75
Soot, (3 burnings)	1.75

TABLE XXXVI.—DEDUCTIONS FROM

Experiments on Lykens

	Nature of the data furnished by the respective tables.	1st trial. (Table XXXIII.)	2d Trial. (Table XXXIV.)
		July 22.	July 24.
1	Total duration of the experiment, in hours	27.25	25.45
2	Duration of steady action, in hours	4.416	5.117
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	9.0	9.0
7	Total weight of coal supplied to grate, in pounds	868.25	874.75
8	Pounds of coal actually consumed	859.5	858.25
9	Pounds of coal withdrawn and separated after trial	8.75	16.5
10	Mean weight, in pounds, of one cubic foot of coal	48.236	48.5977
11	Pounds of coal supplied per hour, during steady action	112.43	76.217
12	Pounds of coal per square foot of grate surface, per hour	7.99	5.417
13	Total waste, ashes and clinker, from 100 pounds of coal	10.025	11.597
14	Pounds of clinker alone, from 100 pounds of coal	4.8197	4.374
15	Ratio of clinker to the total waste, per cent.	48.075	37.717
16	Total pounds of water supplied to the boiler	6982.0	7726.0
17	Mean temperature of water, in degrees Fahrenheit	78°.8	80°.3
18	Pounds of water supplied at the end of experiment, to restore level	379.0	320.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	49.0	39.0
20	Pounds of water evap. per hour, during steady action	859.37	814.61
21	Cubic feet of water per hour, during steady action	13.75	13.034
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.276	2.158
23	Pounds of water per square foot, by a mean of several observations	2.197	2.234
24	Water evap. by 1 of coal, from initial temp. (a) final result	8.0663	8.9566
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	7.643	10.688
26	Pounds of fuel evaporating one cubic foot of water	7.7127	6.9781
27	Mean temperature of air entering below ash pit, during steady pressure	76°.7	89°.73
28	Mean temp. of wet bulb thermom., during steady pressure	64°.0	73°.64
29	Mean temperature of air, on arriving at the grate	268°.3	244°.91
30	Mean temperature of gases, when arriving at the chimney	258°.0	277°.55
31	Mean temperature of steam in the boiler	232°.0	232°.18
32	Mean temperature of attached thermometer	74°.5	85°.14
33	Mean height of barometer, in inches	30.072	29.933
34	Mean number of volumes of air in manometer	5.136	5.25
35	Mean height of mercury in manometer, in atmospheres	.5434	.532
36	Mean height of water in syphon draught gauge, in inches	.2988	.3123
37	Mean temperature of dew point, by calculation	58°.95	68°.05
38	Mean gain of temp. by the air, before reaching grate	191°.6	155°.18
39	Mean difference between steam and escaping gases	25°.33	45°.666
40	Water to 1 of coal, corrected for temp. of water in cistern	8.038	8.9236
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.076	10.0675
42	Pounds of water, from 212°, to one cubic foot of coal	437.89	489.23
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.0872	11.388
44	Mean pressure, in atmospheres, above a vacuum	1.4293	1.4151
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.3404	6.1307
46	Condition of the air plates, at the furnace bridge	Closed.	Open (6 rows.)
47	Inches opening of damper, (U. upper, L. lower)	U. 8	U. 8

TABLES XXXIII, XXXIV, XXXV.
valley anthracite coal.

3d Trial. (*Table XXXV.*)	Averages.	Remarks.
July 25.		
24.75		
4.666		
14.07		
377.5		
18.75		
8.0		
782.0		
753.25		
28.75	18.0	It appears that when the combustion was conducted with the damper drawn eight inches, in the first and second trials, the mean amount of unburnt anthracite was but 12.62 lbs.; while with a four-inch damper it was 28.75 lbs.
48.875	48.5696	
103.41	97.352	
7.349	6.919	
15.114	12.245	
4.0142	4.4026	
26.737	37.5096	
6283.0		
83°.6		
500.0		
63.0		
743.46	805.813	
11.89	12.891	
1.969	2.134	
1.983		
8.2575	8.7601	
7.191	8.507	
7.5689	7.4199	
86°.08		
68°.5		
277°.17	263°.46	
260°.0	265°.183	
230°.58		
84°.33		
30.119		
5.24		
.528		
.269	.2933	
60°.75		
191°.09	165°.957	
28°.77	34°.255	
8.223	8.4282	
9.2448	9.4628	
451.84	459.658	
10.8905	10.7886	
1.4165	1.4208	
6.1513	6.2075	
Closed.	-	It appears from line 43 that the open air plate proved beneficial to this coal, so far as evaporative efficiency is concerned; but from lines 20 and 21, it does not appear that the boiler acted so rapidly on the second as on the first day's operations.
U. 4		

Remarks on the foregoing table of deductions.

The results of the three trials of Lykens valley anthracite prove, that on the first day, when 112.43 pounds of coal were supplied to the grate per hour, the rate of evaporation was 13.75 cubic feet of water per hour, and that the final result of water to 1 of coal, from 212°, was but 9.076. The air plate at the furnace bridge was closed. At the next trial, the plate was half uncovered, admitting air through six rows of its apertures. The rate of supplying coal was then only 76.22 pounds per hour, and the evaporation 13.03 cubic feet of water per hour. On that occasion the water from 212° to 1 of coal, was 10.067—being a gain of rather more than 11 per cent. This was the highest result obtained with the coal under consideration. It appears that on the third trial, with the air plate *closed* and the damper drawn but 4 inches, the evaporation was reduced to 11.89 cubic feet per hour; while the coal supplied was 103.41 pounds, and the water to 1 of coal, from 212°, in the final result, was 9.245. In line 13, it will be seen that the amount of waste on the three several days of trial was 10.025, 11.597, and 15.114 per cent., respectively.

These facts point to the necessity of conducting the combustion of this anthracite either with a small supply of air thrown in above the ignited mass, or with only a thin stratum of coal upon the grate.

It will be seen, on reference to the 15th line of the table, that, on the first trial, the vitrified portion of the waste matter was 48 per cent. of the whole, and but 26.7 per cent. of it on the third. This again confirms the position already laid down relative to the action of a rapid combustion, and a consequent high temperature, in determining the vitrification of earthy materials. The facility with which these materials are fused would, in the case of employing this anthracite for the smelting of iron, afford the advantage of a ready conversion into cinder, creating no additional demand for *flux*, and requiring no great elevation of temperature for that purpose.

From lines 29 and 30, it appears that the air, in traversing the chambers between the double walls of the furnace, and passing under the fire flue, became heated to an average temperature of 263°, and that the products of combustion left the boiler at 265°, or about 34° higher than the contemporaneous temperature of the steam in the boiler.

From the 39th line of the table, it is apparent that, on the second trial, with six rows of apertures in the air plate open, the gases escaped from the boiler with nearly twice as much excess of temperature above the steam as on the preceding day, when the whole remained closed. This fact, together with the superior evaporative effect already noticed, appears conclusive as to the advantage of a supply of air thrown in above the fuel.

From the average in line 42, it is evident that 1 cubic foot of this anthracite evaporated nearly 460 pounds of water from a temperature of 212°; the lowest result being 438, and the highest 489.

No. 8.

Beaver Meadow anthracite—part of a stock procured for use in the U. S. Steamer Union.

This coal had so near a resemblance to the samples of Beaver Meadow coal sent for trial by the company, that little needs to be said in relation to its characters. It was broken to a pretty uniform size of lumps of about 4 inches in diameter ; and the weight of 1 cubic foot was, on an average, 55.084 pounds. This will show that 40.65 cubic feet of space are required to stow 1 ton.

It was with coal of this sample that were afterwards made the experiments of mixing and burning together, in one case, bituminous coal of the Midlothian (Virginia) mines, and in another, that of Cumberland in Maryland, in the proportions by measure of one-fifth bituminous to four-fifths anthracite.

There were two varieties of this anthracite landed at the yard nearly at the same time, and thrown in two separate heaps. The coal for one day's burning was taken from each heap. By reference to the table of deductions following those of the experiments, and a comparison of the results which it furnishes with those found at pages 45 and 61, and which relate to the two samples sent for trial by the Beaver Meadow company, it will be seen that the coal now under consideration was 4.86 per cent. inferior in evaporative effect to the mean of those samples.

TABLE XXXVII.—BEAVER MEADOW

First variety—upper damper 12

Date.	Hour.	TEMPERATURES OF THE							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m. A. M.													
April 12	9.15	53	-	154	242	51	222	-	30.06	0.130	9 29	0.19	-	129.50
	9.45	55	-	158	244	52	221	-	30.06	0.170	8.90	0.20	-	113.50
	10.30	56	-	172	240	52	226	-	30.06	0.173	8.86	0.20	-	113.00
	11.00	56	-	178	262	52	229	-	30.07	0.182	8.78	0.20	-	-
	11.30	56.5	-	180	268	52	230	-	30.05	0.183	8.76	0.21	-	110.50
	P. M.													
	0.30	57	-	212	270	52	228	-	30.05	0.190	8.69	0.20	495	-
	1.00	56	-	226	278	53	230	-	30.05	0.189	8.70	0.21	745	109.00
	1.20	56	-	234	280	53	228	-	30.06	0.188	8.71	0.21	1260	-
	2.00	56	-	252	284	52	229	-	30.05	0.196	8.62	0.22	1605	109.50
	3.00	56	-	260	296	51	230	-	30.05	0.200	8.58	0.25	2185	-
	3.45	56	-	268	292	51	230	-	30.05	0.186	8.725	0.24	2790	111.75
	4.45	56	-	276	270	51	231	-	30.05	0.223	8.34	0 30	3300	-
	5.30	55	-	282	282	51	229	-	30.04	0.193	8.66	0.28	4730	111.75
	6.30	54	-	290	260	51	229	-	30.03	0.193	8.66	0.28	4875	112.25
	7.20	54	-	306	280	51	229	-	30.04	0.193	8.66	0.27	5340	-
	8.00	54	-	320	268	51	229	-	30.04	0.190	8.69	0.26	5920	-
	8.15	-	-	-	-	-	-	-	-	-	-	-	6495	-
	A. M.													
April 13	5.45	53	-	174	172	52	210	-	30.02	-	-	0.16	7060	-

Steady action, 7 hours; coal supplied to grate, 554.25 lbs.; water to boiler, 4,875 lbs.; hence, water to 1 of coal, 8.795.

ANTHRACITE COAL, FROM NAVY YARD.

inches open; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet; grate 7 inches below boiler.
h. m.					Commenced firing at 7*h.* 5*m.* a. m.
9.15	-	101	+20	-	Wood consumed, 171 lbs.; commenced charging with coal.
9.45	-	103	23	-	To the first charge was added 18½ lbs. of coke of the same coal, making in all 129.5 lbs.
10.30	-	116	14		
-	-	122	33		
11.30	-	123.5	38		
-	-	155	42	1.311	
1.00	-	170	48	1.324	
-	-	178	52	-	Filled tank.
2.00	-	196	55	2.278	
-	-	204	66	1.537	Beginning to rain.
3.45	-	212	62	2.140	
-	-	220	39	1.351	Lower damper opened a few minutes.
5.30	-	227	53	-	Water gauge obstructed, causing the boiler to be overcharged.
6.30	-	236	31	2.384	Filled tank.
-	-	252	51	1.478	
-	-	266	39	2.304	Contents of ash pit thrown on grate.
-	-	-	-	-	Water 2.2 inches above normal level.
-	-	121	—38	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	12.25
Ashes - - - - - - - - - -	50.25
Ashes behind bridge - - - - - - - - -	6.25
Total clinker and ashes - - - - - - - -	68.75
Deduct wood ashes - - - - - - - - -	0.525
Total waste from coal - - - - - - - -	68.225
Coke - - - - - - - - - -	112.33

TABLE XXXVIII.—BEAVER MEADOW

Second variety—

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
April 13	7.00	54	-	140	172	53	210	-	30.02	-	-	0.20	-	-
	7.55	54	-	158	222	54	224	-	30.02	0.120	9.39	0.20	-	108.00
	8.40	55	-	162	192	53	220	-	30.02	0.186	9.74	0.17	470	108.00
	10.30	56	-	168	192	54	220	-	30.02	0.120	9.39	0.20	580	108.25
	11.40	56.3	-	160	190	52	222	-	30.02	0.128	9.21	0.20	630	108.50
	P. M. 0.40	56	-	156	284	53	226	-	30.00	0.172	8.88	0.20	630	-
	1.00	56	-	160	278	52	226	-	29.99	0.168	8.96	0.20	630	111.25
	3.20	57	-	170	282	53	229	-	29.95	0.190	8.69	0.23	1030	-
	4.25	56.5	-	182	288	52	230	-	29.95	0.186	8.72	0.22	1740	108.75
	5.40	56	-	196	268	52	225	-	29.92	0.181	8.78	0.28	2485	110.00
	7.00	56	-	213	292	52	229	-	29.91	0.193	8.65	0.28	3105	108.75
	8.00	55.5	-	238	284	53	229	-	29.91	0.190	8.69	0.28	3935	108.25
	8.40	55	-	255	275	52.5	229	-	29.91	0.193	8.65	0.28	4323	110.00
	9.15	56	-	268	270	53	230	-	29.92	0.193	8.65	0.29	4850	-
	10.00	55.5	-	275	270	54	228.5	-	29.92	0.190	8.69	0.28	5790	-
April 14	A. M. 7.25	55	-	190	210	56	220	-	29.88	0.096	9.64	0.21	8187	-

Period of steady action this day from 1*h*. p. m. to 8*h*. 40*m*. p. m. = 7*h*. 40*m*.; coal supplied to grate, 545.75 lbs.; water to boiler, 3,693 lbs.

ANTHRACITE COAL, FROM NAVY YARD.

air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet; grate 7 inches below the boiler.
h. m.					
-	-	86	—38		
7.55	-	104	— 2	-	Wood consumed, 112 lbs. 6 oz.; commenced charging with coal.
8.40	-	107	—28	1.556	Lower damper open; temperature of gases taken at upper flue.
10.30	-	112	—28	0.159	
11.40	-	103.7	—32	0.113	Temperature taken at upper flue; at lower flue it was 248°.
-	-	100	+58	-	Temperature of gases taken at lower flue.
1.00	-	104	52	-	Temperature of gases taken at lower flue; raining.
....		....	....	....	
-	-	113	53	0.289	Temperature taken at upper flue; the lower closed.
4.25	-	125.5	58	1.736	
5.40	-	140	43	1.568	The recorded temperature of steam in boiler is probably an error of observation; raining violently.
7.00	-	157	63	1.231	
8.00	-	182.5	55	2.198	Damper reduced to 8 inches.
8.40	-	200	46	1.542	
....			....	....	
-	-	212	40	2.075	
-	-	219.5	41.5	3.320	Contents of ash pit thrown on grate.
		....			
-	-	195	—10	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	14.50
Ashes	65.50
Ashes behind bridge	6.25
Total clinker and ashes	86.25
Deduct wood ashes	0.345
Total waste from coal	85.905
Coke	101.83

TABLE XXXIX.—DEDUCTIONS

Experiments on Beaver Meadow

	Nature of the data furnished by the respective tables.	1st Trial. (Tab. XXXVII.)	2d Trial. (Tab. XXXVIII.)
		April 12.	*April* 13.
1	Total duration of the experiment, in hours	22.66	28.082
2	Duration of steady action, in hours	7.0	7.66
3	Area of grate, in square feet	16.25	16.25
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.66	21.66
6	Number of charges of coal supplied to grate	9.0	10.0
7	Total weight of coal supplied to grate, in pounds	1020.75	1089.75
8	Pounds of coal actually consumed	908.42	987.92
9	Pounds of coal withdrawn and separated after trial	112.33	101.83
10	Mean weight, in pounds, of one cubic foot of coal	55.68	54.4875
11	Pounds of coal supplied per hour, during steady action	79.178	71.181
12	Pounds of coal per square foot of grate surface, per hour	4.872	4.38
13	Total waste, ashes and clinker, from 100 pounds of coal	7.512	8.6955
14	Pounds of clinker alone, from 100 pounds of coal	1.3375	1.4617
15	Ratio of clinker to the total waste, per cent.	17.809	16.809
16	Total pounds of water supplied to the boiler	7060.0	8187.0
17	Mean temperature of water, in degrees Fahrenheit	51°.3	53°.8
18	Pounds of water supplied at the end of experiment, to restore level	565.0	2330.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	84.0	342.0
20	Pounds of water evaporated per hour, during steady action	696.428	481.8
21	Cubic feet of water per hour, during steady action	11.142	7.709
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.8448	1.2763
23	Pounds of water per square foot, by a mean of several observations	1.7607	1.427
24	Water evaporated by 1 of coal, from initial temp. (a) final result	7.6792	7.9409
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	8.7956	6.7322
26	Pounds of fuel evaporating one cubic foot of water	8.1389	7.8706
27	Mean temp. of air entering below ash pit, during steady pressure	55°.57	55°.93
28	Mean temp. of wet bulb thermometer, during steady pressure	–	–
29	Mean temperature of air, on arriving at the grate	252°.61	224°.62
30	Mean temperature of gases, when arriving at the chimney	276°.15	278°.62
31	Mean temperature of steam in the boiler	229°.308	228°.7
32	Mean temperature of attached thermometer	53°.0	53°.0
33	Mean height of barometer, in inches	30.048	29.933
34	Mean number of volumes of air in manometer	8.6596	8.69
35	Mean height of mercury in manometer, in atmospheres	0.198	0.190
36	Mean height of water in syphon draught gauge, in inches	0.2433	0.2616
37	Mean temperature of dew point, by calculation	–	–
38	Mean gain of temperature by the air, before reaching grate	197°.04	168°.69
39	Mean difference between steam and escaping gases	46°.842	49°.92
40	Water to 1 of coal, corrected for temp. of water in cistern	7.7277	7.9966
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	8.9334	9.2248
42	Pounds of water, from 212°, to 1 cubic foot of coal	497.45	502.64
43	Water, from 212°, to 1 pound of combustible matter of the fuel	9.659	10.1034
44	Mean pressure, in atmospheres, above a vacuum	1.4291	1.4218
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.3374	6.2291
46	Condition of the air plates, at the furnace bridge	Removed.	Removed.
47	Inches opening of damper, (U. upper, L. lower)	U. 12	L. 10, U. 6&12

FROM TABLES XXXVII, XXXVIII.

anthracite coal, from navy yard.

Averages.	Remarks.
167.08	The large amount of coal left on the grate is attributable, in part, no doubt, to the deficiency of draught; but by reference to page 45 it will be seen that the Beaver Meadow sample, from slope No. 3, gave, on an average, 112.37 pounds; almost identical with that found on the first trial here recorded.
55.0837	
75.1795	
4.626	
8.1037	
1.3996	
17.309	
589.114	
9.4255	
1.5605	
7.81	
7.7639	
8.0047	
-	No observations on this subject taken at this period.
236°.615	
277°.385	
0.2524	The height of chimney-(41 feet) was probably too low to give the most useful effect to this coal.
-	(Observations for this deduction not taken.)
182°.865	
48°.381	
7.8622	
9.0791	
500.045	
9.8812	
1.4255	
5.2833	

No. 9.

"Natural coke," from Tuckahoe, Virginia, sent by Messrs. Barr and Deaton.

The following letter relates to this sample:

"RICHMOND, *July* 1, 1842.

"DEAR SIR: Annexed you have a receipt from Captain Shorter, schooner Presto, for two tons natural coke, (all lumps,) to be tested as fuel for war steamers. It is from a mine just opened on Tuckahoe, Virginia.

"We were advised by Mr. F. B. Deane, whom you know, to forward this thus late—knowing it to be a new article, and believing you would, at your leisure, give it a trial, should it not arrive in time for the general test. The heat from it is intense, and it answers well in our pit engines.

"Yours, respectfully,

"BARR & DEATON.

"WILLIAM B. SCOTT, Esq."

The exterior appearance of this material is very different from that of any of the anthracites heretofore described, and equally or more so from that of all the bituminous coals which will hereafter come under notice. It is of a uniformly dull black, or merely glimmering lustre; the surfaces of deposition appearing in many specimens to be distorted, or almost wholly obliterated. In others, fractures occur along those surfaces; but the fossils which, in coal, usually occupy those spaces, are nearly undistinguishable. The spaces are found occupied, in a great measure, by sulphate of iron. This substance gives rise, during the combustion, to the development of sulphurous fumes excessively oppressive to the organs of respiration. There appears to be scarcely more regularity of form in the masses of this material than in those of common anthracite. When reduced to powder, it becomes perfectly black, and the streak on white earthenware is of the same color.

One specimen (*a*) of this material had a specific gravity of 1.305; another (*b*) 1.3413. The mean of these gives the calculated weight per cubic foot 82.695 pounds.

Forty-seven experiments proved the actual average weight per cubic foot to be 46.635 pounds; the highest being 54.75, and the lowest 40.5. Hence the ratio of the actual to the calculated weight is 0.5639 : 1. The space required per ton is 48.032 cubic feet.

The moisture expelled in drying *a* at 216° was 0.962, and that from *b*, 0.775. 28 pounds exposed for four days in the steam drying apparatus lost 1.116 per cent.

Of other volatile matter, *a* lost by mean of two trials 10.428, and *b* 14.045. The sulphur procured from *b* was 0.466 per cent. The total volatile matter obtained from one specimen tried by Dr. King was 13.916, and that from another 12.25. The mean of these is 13.105; while the mean of the two above stated (including moisture) is 13.083.

Of earthy matter, specimen *a* gave, by a mean of four incinerations, 10.991; and by four others, 11.15—mean 11.07; *b* gave 2.44 and 3.07, or a mean of 2.755 per cent. The higher numbers in both of these cases are probably due to the more complete peroxidation of the iron in one set of trials than in the other.

During the experiments on evaporation, there were burned 4,209 pounds of this coke, from which were obtained 551.5 pounds of ashes, weighing 56.98 pounds per cubic foot; 225.75 pounds of clinker, weighing 38.25 pounds per cubic foot; and 11.5 pounds of soot and dust from the flues, weighing at the rate of 22.67 pounds per cubic foot. Of this latter material, the carbonaceous portion was doubtless due almost entirely to the wood used in heating up the boiler. A reincineration left of the

Ashes - - -	52.78	per cent. incombustible.
Clinker - - -	90.37	"
Soot - - - -	46.66	"

Hence the absolutely incombustible matter in the state of

Ashes, is - - - - -	291.080	pounds.
Clinker - - - - -	204.105	"
Dust or soot - - - - -	5.366	"
Total - -	500.551	"

From this deducting the ashes of 905.2 pounds of wood = 2.777 pounds, we have left 497.774 pounds = 11.826 per cent., or 4.914 per cent. more than the mean of the two specimens above analyzed.

The data furnished by the analyses show that the two specimens had the following constituents:

	Specimen *a*.	
Moisture - - - -	0.962	
Sulphur - - - -	(not tried)	
Other volatile matter - - -	10.428	
Earthy matter - - -	11.070	
Fixed carbon - - - -	77.540	
	100.	100.
Volatile to fixed combustible	1 : 7.435	1 : 6.068

The operations on a large scale afford the following, viz:

Moisture, from 28 pounds - - -	1.116	per cent.
Other volatile matter, from four specimens -	11.977	"
Earthy matter, from 4,209 pounds - -	11.826	"
Fixed carbon, by difference - - -	75 081	"
Volatile combustible to fixed carbon - -	1 : 6.2688	

The clinker of this fuel is externally of a reddish-brown color, black on the interior, tending to spread into continuous masses, but not seriously impeding the grate. In one instance, however, it was found necessary to remove a portion, to maintain a uniform action of the boiler. An oppressive odor of sulphurous acid, evidently derived from the decomposition of the sulphate of iron, was the consequence of exposing this clinker while hot on the open hearth of the furnace.

Among the soot and dust of the flues, withdrawn after burning this coke, was found a considerable quantity of sulphuric acid; 157.9 grains of the dust being digested at a temperature below boiling point for twenty hours, and then filtered, was found to contain free sulphuric acid. Chloride of baryum afforded a precipitate of sulphate of baryta, which, being filtered out and ignited, weighed 22.9 grains—showing the sulphuric acid to be 4.98 per cent. of the weight of dust assayed. The presence of this material in so considerable quantities must doubtless prove highly injurious to the metals with which it comes in contact.

Of specimen *b*, 20 grains treated with litharge yielded 626.88 grains of metallic lead, or 31.344 times its own weight. Deducting moisture and earthy matter, the lead to 1 of combustible is 32.491.

The trial of this coke in an office grate exhibited the following phenomena: When laid on a bed of ignited coke, it remained for twenty or thirty minutes with little or no emission of flame. It then began to yield a portion of blue flame, which, as the heat increased, passed into a yellowish white, intermixed with blue, and rising to the height of 12 or 15 inches. This character of affording a pretty long flame had been noticed in the experiments on evaporation.

This fuel burns with about the same activity as Lykens valley anthracite. On becoming fully ignited, it throws out an intense heat, accompanied with the blue flame of an anthracite fire. Being more porous than the latter, and exposing more surface to the action of the air, it burns more rapidly, and with proportionate intensity of heat. By projecting a little water on the ignited mass, the blue is changed to a crimson-colored flame.

This coke would be more suitable for hall stoves and house-heating furnaces than for open grates, especially if the former were so constructed as to confine the strong sulphurous fumes.

The time required to bring the boiler to steady action was 1.745 hour, or about ⅔ of an hour less than was required by the Lykens valley anthracite.

The quantity left unburnt at the conclusion of each experiment was 43.687 pounds. The very large proportion of combustible matter found in the ashes by reincineration (47.22 per cent. of their weight) indicates that a rapid disintegration occurs during the combustion. This effect rendered it frequently necessary to replace the contents of the ash pit on the grate, in order to secure a satisfactory combustion.

It cannot be recommended for use in smiths' fires, owing to the large amount of sulphur, and the high proportion of earthy constituents. With a very slow rate of combustion, which would leave a large portion of its residue unvitrified—such a rate, for example, as is used in Cornwall, where the water evaporated by a square foot of absorbing surface is but about nine-tenths of a pound per hour—this material would afford a steady durable heat, with but little impediment to the passage of air through the grate.

A reference to the deductions table XLIV, will show that, on an average, as seen in line 26, it took 8.34 pounds of coke to evaporate 1 cubic foot of water, and that the cubic foot of coke evaporated from 212° 395.3 pounds of water, while the same bulk of Lykens valley anthracite, to which its action bears a stronger analogy than to that of any other of this class, produced 459.6 pounds of steam.

In line 39 of the table of deductions, it will be seen that when the air plates at the furnaçe bridge were open, the gases passed to the chimney at a mean temperature above that of the steam, for the two days on which that arrangement was adopted, of 46°.74; while on the two days when the air plate was closed, the mean excess of temperature was only 38°.5. This, as well as the slight superiority in evaporative effect observed in the 43d line, when the air plate was open, led to the conclusion that some portion of combustible gases escaped combustion when the air plate was closed.

TABLE XL.—

First trial—upper damper 10

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. P. M.													
June 17	0.00	71	63	165	232	76	188	-	30.06	-	-	0.25	-	-
	0.35	71	63	194	255	76	229	-	30.06	0.524	5.33	0.25	-	87.00
	0.50	70	63	192	255	76	230	-	30.04	0.526	5.30	0.27	162	85.00
	1.05	69.5	62	193	270	76	233	-	30.02	0.560	4.98	0.40	310	87.25
	1.30	70	62	207	280	76	233	-	30.02	0.562	4.96	0.38	638	97.50
	1.50	74	65	224	260	75	232	-	30.04	0 561	4.97	0.38	975	-
	2.10	74	64	236	260	76	233	-	30.04	0.553	5.04	0.38	1310	90.25
	2.30	73	65	250	240	76	233	-	30.04	0.550	5.08	0.30	1562	-
	2.50	75	65	280	245	76	232	-	30.03	0.550	5.08	0.33	1907	98 75
	3.10	76	63	306	242	76	232	-	30.03	0.537	5.20	0.30	2249	98.75
	3.30	76	64	316	250	76	232	-	30.03	0.535	5.22	0 30	-	-
	3.50	76	65	326	......	76	232	-	30.03	0.548	5.10	0.30	2588	101.25
	4.10	77	68	340	225	76	232	-	30.03	0.543	5.14	0.35	2925	-
	4.30	77	67	345	260	76	232	-	30.03	0.550	5.08	0.33	3082	-
	5.00	80	67	346	265	76	232	-	30.03	0.545	5.12	0.34	3410	101.25
	5.30	80	68	360	234	76	231	-	30.03	0.533	5.24	0.30	3743	-
	6.00	80	66	368	272	76	232	-	30.03	0.548	5.10	0.35	4163	86.25
	6.20	88	70	382	230	76	232	-	30.03	0.527	5.30	0.30	4415	-
	6.35	82	66	-	-	76	-	-	30.04	0.503	5.54	-	4980	-
	P. M.													
June 18	2.00	75	63	180	185	76	220	-	30.12	0.406	6 49	0.14	4980	-
	2.45	75	63	184	182	76	208	-	30.12	0.350	7.06	0.13	6620	-

Period of steady action from 1*h.* 5*m.* p. m. to 5*h.* 50*m.*—4*h.* 45*m.*; coke supplied to the grate, 674 lbs.; water to boiler, 3,713 lbs.

NATURAL COKE.

inches open ; air plates closed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Commenced firing at 8*h*. a. m.
-	58.1	94	+44	-	Water 0.3 inch below normal level. By an escape of air from the manometer since last experiment, the volumes are now reduced to 4.1625 at 32° Fahr., and barometer at 30 inches; steam at equilibrium at 0*h*. 35*m*. p. m.
0.35	58.7	123	26		
1.00	58.7	122	25	1.717	
1.05	58.6	123.5	37	1.568	Wood consumed, 567½ lbs.; commenced charging with coke at 0*h*. 35*m*. p. m.; steam blows off at 0*h*. 50*m*. p. m.
1.40	56.9	137	47	2.085	
-	60.1	150	28	2.678	
2.05	58.3	162	27	2.662	
-	60.6	177	7	2.002	
2.40	59.5	205	13	2.741	
3.05	55.3	230	10	2.718	
-	60.8	240	18	-	Clear.
3.45	59.1	250	-	1.346	Commenced drawing gases at 3*h*. 50*m*. p. m.; drew in 10 minutes 100 cubic inches, which gave water 0.76 grain, carbonic acid 4.5 grains, oxygen 11.11, (reduced to 60° and 30 inches barometer.)
-	63.7	263	-	2.678	
-	62.1	268	28	1.247	The 8th and 9th charges were almost all fine coke.
4.50	60.7	269	33	1.737	
-	62.4	280	3	1.764	
5.50	58.9	288	40	2.225	
-	62.6	294	— 2	2.003	Contents of ash pit thrown on grate; damper reduced to 5 inches.
-	58.0	-	-	-	Water in boiler left at 1.6 inch above normal level.
-	55.9	105	—35	-	Water not visible in glass tube of gauge.
-	55.9	109	—26	-	Water adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	44.25
Ashes - - - - - - - - - - -	127.75
Ashes behind bridge - - - - - - - - -	7.34
	179.34
Deduct wood ashes - - - - - - - - -	1.74
Total waste from coke - - - - - - - -	177.60
Coke unburnt - - - - - - - - -	31.75

TABLE XLI.—

Second trial—upper damper 10 inches open ;

														Weight of charges of coal.
June 19	5.15	[illegible]	[illegible]	150	-	73	186	-	[illegible]	[illegible]	6.95	0.15	-	-
	6.10	66	60	139	230	[illegible]	202	-	30.19	0.361	6.94	0.24	-	-
	6.25	67	60	139	210	73	217	-	30.21	[illegible]	6.26	-	-	-
	7.13	68	61	142	210	[illegible]	226	-	30.22	[illegible]	5.59	0.20	-	92.75
	8.00	[illegible]	61	144	242	72	229	-	[illegible]	0.530	5.28	0.18	-	86.50
	8.30	70	61	148	273	[illegible]	232	-	[illegible]	0.544	5.12	0.25	158	-
	[illegible]	70	60	[illegible]	293	72	232	-	30.24	0.544	5.12	0.27	492	94.25
	9.20	72	61	[illegible]	290	72	232	-	30.24	[illegible]	5.10	0.26	660	92.00
	9.40	74	61	168	295	72	232	-	30.24	0.553	5.04	[illegible]	915	-
	[illegible]	74	61	170	292	[illegible]	232	-	[illegible]	0.550	5.08	0.26	1170	-
	10.20	76	63	178	265	72	232	-	30.23	0.544	5.14	0.22	1510	93.75
	10.40	76	62	182	275	72	232	-	[illegible]	0.544	5.14	0.22	1675	-
	11.00	76	61	188	275	72	[illegible]	-	[illegible]	[illegible]	5.12	0.22	1930	-
	11.20	78	62	190	275	72	232	-	30.26	0.539	5.18	0.21	2187	94.50
	11.40	78	63	196	265	72	232	-	30.26	0.548	5.10	0.25	2362	-
	P. M.													
	0.00	78	62	198	282	[illegible]	232	-	30.25	0.548	5.10	0.24	2615	84.00
	0.20	[illegible]	63	202	280	72	[illegible]	-	30.26	0.548	5.10	0.24	2875	-
	[illegible]	79	63	206	260	72	232	-	[illegible]	0.552	5.06	0.26	3220	-
	1.00	78	[illegible]	210	275	72	232	-	30.25	0.548	5.14	0.21	3352	68.50
	1.30	80	63	226	250	72	232	-	30.26	0.540	5.16	0.24	[illegible]	-
	2.00	[illegible]	64	232	250	77	232	-	30.26	[illegible]	5.02	0.26	3910	[illegible]
	2.30	81	65	[illegible]	255	77	[illegible]	-	30.26	[illegible]	5.22	0.20	4400	-
	3.00	83	64	254	265	77	232	-	30.25	0.548	5.14	0.25	[illegible]	87.75
	[illegible]	82	[illegible]	252	280	77	232	-	30.25	[illegible]	5.05	0.30	5160	-
	4.00	83	62	253	258	78	232	-	30.26	[illegible]	5.12	0.25	5562	97.75
	4.30	82	63	272	268	[illegible]	232	-	30.25	[illegible]	5.10	0.24	6010	[illegible]
	[illegible]	83	63	272	270	[illegible]	232	-	30.26	[illegible]	5.10	0.26	[illegible]	[illegible]
	5.30	86	66	276	282	78	232	-	30.25	0.539	5.16	0.22	6780	-
	6.00	86	66	210	[illegible]	[illegible]	[illegible]	-	30.25	0.519	[illegible]	0.16	7636	-
	A. M.													
June 20	4.15	60	[illegible]	220	210	76	[illegible]	-	30.32	0.514	5.42	0.16	7640	-
-	5.15	60	[illegible]	210	210	[illegible]	212	-	30.32	[illegible]	6.80	0.18	8973	-

Period of steady action assumed to be from 9*h*. 30*m*. a. m. to 5*h*. 10*m*. p. m.=7*h*. 40*m*.; coke supplied to grate, 816.75 lbs.; water to boiler, 5,713 lbs.; hence, water to 1 of coke=6.993.

NATURAL COKE.

air plates open; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	55.8	87	-	-	Water 0.15 inch below normal level; commenced firing.
-	55.7	73	+28	-	Water at normal level; wind NNE.; clear.
-	55.0	72	23	-	Water 0.2 inch above normal level.
7.13	56.3	74	—16	-	Wood consumed, 186¼ lbs.; commenced charging with coke.
8.00	55.0	74	+13	-	Steam beginning to blow off; filled tank; air plates opened at 8*h*. 13*m*. a. m.
-	55.0	78	41	0.837	Wind W., light; clear.
9.00	53.0	88	61	1.769	
9.30	53.7	90	58	1.335	
-	52.5	94	63	2.026	
-	52.5	96	60	2.026	
10.10	55.3	102	33	2.702	
-	53.4	106	43	1.311	
-	51.3	112	43	2.026	Commenced drawing gases at 11*h*. 5*m*. a. m.; drew in 10 minutes 60 cubic inches; which gave water, 0.43 grain; carbonic acid, 2.67 grains; oxygen, 7.66 cubic inches.
11.20	52.2	112	43	2.042	
-	54.2	118	33	1.391	
0.00	52.2	120	50	2.011	
-	53.2	122	48	2.066	Commenced drawing gases at 0*h*. 32*m*. p. m.; drew in 12 minutes 80 cubic inches; which gave water, 1.03 grain; carbonic acid, 3.76 grains; oxygen, 12.176 cubic inches.
-	53.7	127	28	2.742	
1.00	54.2	132	43	1.049	
-	53.2	146	18	2.649	
2.10	55.2	152	18	-	Filling tank; water 0.4 inch below level; tank filled at 2*h*. 10*m*. p. m.
-	55.2	162	23	1.452	Drew out clinker from fire; gave off strong sulphurous fumes.
2.45	53.7	171	33	2.303	
-	54.2	170	48	1.722	Commenced drawing gases at 3*h*. 32*m*. p. m.; drew in 13 minutes 100 cubic inches; which gave water, 0.82 grain; carbonic acid, 4.86 grains; oxygen, 12.12 cubic inches. Wind E.; clear.
3.50	49.5	170	26	2.236	
4.30	52.1	190	36	2.267	
5.10	51.6	189	38	1.854	
-	55.3	188	50	2.225	Contents of ash pit thrown on grate; air plates closed; filled tank at 6*h*. p. m.
-	56.2	124	— 9	-	Water in boiler 1.9 inch above normal level; damper reduced to 3 inches.
-	48.1	160	—18	-	Fire on grate; water in boiler, 2.7 inches below normal level.
-	48.1	150	— 2	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	71.25
Ashes	110.25
Ashes behind bridge	9.30
Total clinker and ashes	190.80
Deduct wood ashes	0.571
Total waste from coke	190.229
Coke unburnt	39.

TABLE XLII.—

Third trial—upper damper 5 inches open;

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 20	5.15	60	54	210	210	76	212	-	30.32	0.376	6.80	0.18	-	-
	6.00	62.5	56	194	230	76	224	-	30.32	0.510	5.46	0.20	-	87.25
	6.30	63	56	194	218	76	228	-	30.32	0.532	5.25	0.18	-	104.00
	7.00	64	58	200	270	76	235	-	30.34	0.547	5.10	0.25	-	-
	7.30	68	60	202	255	76	229	-	30.34	0.545	5.12	0.18	247	109.50
	8.00	70	62	213	258	72	228	-	30.35	0.537	5.20	0.20	247	-
	8.30	72	64	214	262	72	229	-	30.36	0.541	5.16	0.20	852	86.00
	9.00	74	65	225	260	72	230	-	30.36	0.538	5.20	0.22	1192	-
	9.30	75	65	228	255	72	230	-	30.36	0,538	5.20	0.18	1482	88.00
	10.00	76	66	242	270	72	232	-	30.36	0.556	5.02	0.30	1902	88.75
	10.30	75.5	65	246	285	72	232	-	30.36	0.552	5.06	0.23	[illegible]	-
	11.00	80	66	256	280	72	231	-	30.37	0.546	5.12	0.23	2752	93.75
	11.30	80	66	268	284	72	232	-	30.37	0.544	5.14	0.22	3172	83.25
	P. M.													
	0.00	81	66	276	290	72	232	-	30.37	0.549	5.10	0.27	3497	-
	0.30	80	66	288	300	72	230	-	30.36	0.554	5.04	0.28	3827	-
	1.00	82	67	302	260	72	231	-	30.34	0.533	5.24	0.22	4245	101.75
	1.30	83	67	314	290	73	231	-	30.34	0.546	5.11	0.28	4495	-
	2.00	84	67	308	324	77	232	-	30.34	0.556	5.02	0.38	4672	100.75
	2.30	85	68	318	295	78	231	-	30.32	0.538	5.20	0.27	5535	90.75
	3.00	83	67	318	300	78	231	-	30.32	0.548	5.10	0.30	6022	-
	3.30	83	66	324	290	78	230	-	30.32	0.542	5.16	0.29	6535	112.50
	4.00	89	69	342	270	78	231	-	30.31	0.536	5.22	0.25	6975	-
	5.30	82	67	380	230	78	228	-	30.31	0.508	5.50	0.20	7699	-
	A. M.													
June 21	5.00	58	55	242	205	77	227	-	30.28	0.510	5.48	0.20	7702	-
	5.35	63	58	228	198	77	220	-	30.28	0.452	6.02	0.20	8284	-

Period of steady action, 6*h.* 15*m.*, (from 9*h.* 15*m.* a. m. to 3*h.* 30*m.* p. m.;) coke supplied to grate, 671.5 lbs.; water to boiler, 5,198 lbs.; hence, the water to 1 of coke is for this time, 7.761.

NATURAL COKE.

air plates open; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	48.1	150	— 2	- -	Water in boiler 0.1 inch above normal level; wind E., clear; commenced firing.
6.00	50.2	131.5	+ 6	-	Wood consumed, 85.75 lbs.; commenced charging with coke; steam at equilibrium.
6.30	49.8	131	—10	-	Second weight placed on safety valves for a few minutes, then removed; air plates opened.
-	53.2	136	+35	-	Second charge all fine.
7.30	54.3	134	26	1.309	
-	56.9	143	30	-	Filled tank.
8.20	59.3	142	33	1.603	Wind NE., clear.
-	60.1	151	30	1.801	
9.15	59.5	153	25	1.536	Wind W.; sun shining occasionally; clouds moving from SSW.
9.50	59.0	166	38	2.225	Dew point, by observation, 57°; fifth and sixth charges in lumps.
-	59.3	170.5	53	1.759	
11.00	58.9	176	49	2.744	
11.30	58.9	188	52	2.225	Commenced drawing gases at 11*h.* 42*m.* a. m.; drew in 14 minutes 100 cubic inches, which gave water, 0.76 grain;
-	58.5	195	58	1.722	carbonic acid, 4.17 grains; oxygen, 14.44 cubic inches.
-	58.9	208	70	1.748	
1.00	59.8	220	29	2.215	Ninth charge fine; tenth charge do.
-	59.4	231	59	1.325	
2.00	59.0	224	92	-	Filling tank commenced at 1*h.* 36*m.*, concluded at 2*h.* 15*m.*; wind E.; clear at 2*h.* 30*m.*
2.20	60.3	233	64	2.755	
-	59.4	235	69	2.580	
3.30	57.5	241	60	2.718	Twelfth charge fine.
-	59.1	253	39	2.231	Contents of ash pit thrown on grate; air plates closed.
-	59.8	298	2	-	Water 1.5 inch above level; damper set at 3 inches.
-	52.2	184	—22	-	Water 0.9 inch below normal level.
-	54.0	165	—22	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	52.50
Ashes - - - - - - - - - - -	161.75
Ashes from behind bridge - - - - - - - - -	9.04
Total clinker and ashes - - - - - - - - -	223.29
Deduct wood ashes - - - - - - - - - -	0.263
Total waste of coke - - - - - - - - -	223.027
Coke - - - - - - - - - - -	61.00

TABLE XLIII.—

Fourth trial—upper damper 5 inches open; air

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.											
June 21	5.35	63	58	77	220	–	30.28	0.452	6.02	0.20	–	–
	6.08	[illegible]	60	77	225	–	30.28	0.520	5.36	0.26	–	89.00
	6.35	65	59	77	226	–	30.28	0.528	5.26	0.25	–	95.75
	7.15	65	60	76	229	–	30.29	0.546	5.12	0.26	168	95.75
	8.00	71	64	72	230	–	30.29	0.549	5.10	[illegible]	168	–
	8.30	74	65.5	72	229	–	30.29	0.544	5.14	0.26	985	101.75
	9.00	75	66	73	230	–	30.29	0.538	5.20	0.26	1398	–
	9.30	78	65	73	230	–	30.28	0.544	5.14	0.26	1653	94.00
	10 00	[illegible]	65	73	230	–	30.27	0.554	5.04	0.28	1999	92.50
	10.30	81	66	73	230	–	30.27	0.544	5.14	0.26	2403	[illegible]
	11 00	81	65	73	230	–	30.27	0.544	5.14	0.26	2748	–
	11.30	81	[illegible]	73	231	–	30.26	0.544	5.14	0.27	3143	95.25
	P. M. 0.00	83	[illegible]	74	232	–	30.25	0.552	5.06	0.27	3633	–
	0.30	86	[illegible]	74	231	–	30.25	0.540	5.17	0.28	4208	89.50
	1.00	[illegible]	[illegible]	75	232	–	[illegible]	0.560	4.98	0.27	4781	92.75
	1.30	84	67	78	232	–	30.24	0.554	5.04	0.25	[illegible]	–
	2.10	86	69	[illegible]	230	–	30.22	0.530	[illegible]	0.23	5725	97.50
	2.30	90	70	79	230	–	30.21	0.528	5.20	0.24	5965	–
	3.00	89	72	[illegible]	230	–	30.21	0.528	5.30	0.23	6293	–
	3.30	92	72	79	229	–	[illegible]	0.520	5.38	0.24	6463	96.25
	5.15	81	71	79	228	–	30.17	0.512	5.46	0.21	7751	–
June 22	A. M. 6.05	[illegible]	[illegible]	79	222	–	30.13	0.456	6.98	0.18	7751	–
	6.35	–	–	80	216	–	30.13	0.388	6.68	–	[illegible]	–

The period of steady action is from 8*h.* 15*m.* a. m. to 3*h.* 25*m.* p. m.=7*h.* 10*m.*; coke supplied to grate, 738.75 lbs.; water to boiler, 6,607.4 lbs.; hence, water to 1 of coke, 7.59 lbs.

NATURAL COKE.

plates closed, and steam thrown out of back valve.

Time each charge was on grate.	[illegible]	[illegible]	[illegible]	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
–	54 0	165	—22	–	Commenced firing; kindled fire in small furnace.
[illegible]	54.3	144	+15	–	Wood consumed, 66 lbs.; steam at equilibrio; commenced charging with coke.
6.35	54.5	141	— 4	–	Steam blows off.
7.15	56.4	135	+39	0.668	Wind SE.
–	59.9	149	[illegible]	–	Filled tank.
8.15	[illegible]	166	36	1.731	
–	61.9	172	30	2.188	
9.10	58.1	[illegible]	38	1.351	
10.00	57.6	183	[illegible]	1 801	Wind NE.; clear.
10.50	[illegible]	194	38	2.172	Seventh charge in lumps.
–	56.6	206	[illegible]	1.828	
11.30	56.6	194	59	2.093	Commenced drawing gases at 11*h.* 35*m.* a. m.; drew in 15 minutes 100 cubic inches, which gave of water 0.80 grain, carbonic acid 6.31 grains.
–	55.6	217	53	2 596	
0.30	[illegible]	232	51	3.046	Commenced drawing gases again at 0*h.* 39*m.* p. m.; drew in 13 minutes 101 cubic inches, which gave water 1.17 grain, carbonic acid 5.44 grains, and oxygen 14.55 cubic inches.
0.50	59.0	254	46	2.771	
–	59.0	276	48	–	Commenced filling tank at 1*h.* 12*m.*; concluded at 2*h.* 55*m.* p. m.
[illegible]	61.6	298	[illegible]	2 257	
–	61.9	308	54	1.907	The coke in drying apparatus now weighs 27 lbs. 11 ounces.
–	[illegible]	[illegible]	32	1.738	Cloudy; wind NE., with sprinkling of rain.
3.25	64.6	318	[illegible]	0.901	Contents of ash pit thrown on grate.
–	66.9	[illegible]	20	–	Water in boiler 1.8 inch above normal level: damper reduced to 9 inches.
–	69.5	139	—44	–	Water in boiler 1.3 inch below normal level; cloudy.
–	–	–	–	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	57.75
Ashes	117.25
Ashes behind bridge	8.82
	183.82
Deduct wood ashes	0.203
Total waste from coal	183.617
Coke	43.09
Soot (4 burnings)	11.5

TABLE XLIV.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (Table XL.)	2d Trial. (Table XLI.)
		June 17.	*June* 19.
1	Total duration of the experiment, in hours	29.5	24.0
2	Duration of steady action, in hours	4.75	7.667
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coke supplied to grate	10.0	13.0
7	Total weight of coke supplied to grate, in pounds	933.25	1183.25
8	Pounds of coke actually consumed	901.5	1144.25
9	Pounds of coke withdrawn and separated after trial	31.75	39.0
10	Mean weight, in pounds, of one cubic foot of coke	46.662	45.81
11	Pounds of coke supplied per hour, during steady action	141.89	106.54
12	Pounds of coke per square foot of grate surface, per hour	10.08	7.572
13	Total waste, ashes and clinker, from 100 pounds of coke	19.70	16.624
14	Pounds of clinker alone, from 100 pounds of coke	4.8597	6.2076
15	Ratio of clinker to the total waste, per cent.	24.668	37.339
16	Total pounds of water supplied to the boiler	6620.0	8973.0
17	Mean temperature of water, in degrees Fahrenheit	76°.0	75°.3
18	Pounds of water supplied at the end of experiment, to restore level	1640.0	1333.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	217.0	176.0
20	Pounds of water evaporated per hour, during steady action	781.68	745.238
21	Cubic feet of water per hour, during steady action	12.5	11.92
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.07	1.974
23	Pounds of water per square foot, by a mean of several observations	2.15	1.991
24	Water evaporated by 1 of coke, from initial temp. (a) final result	7.1026	7.688
25	Water evaporated by 1 of coke, from initial temp. (b) during steady action	5.508	6.993
26	Pounds of fuel evaporating one cubic foot of water	8.7996	8.1296
27	Mean temp. of air entering below ash pit, during steady pressure	75°.54	78°.0
28	Mean temp. of wet bulb thermometer, during steady pressure	65°.07	62°.45
29	Mean temperature of air, on arriving at the grate	292°.57	207°.41
30	Mean temperature of gases, when arriving at the chimney	250°.21	272°.32
31	Mean temperature of steam in the boiler	232°.1	232°.0
32	Mean temperature of attached thermometer	73°.0	75°.0
33	Mean height of barometer, in inches	30.031	30.246
34	Mean number of volumes of air in manometer	5.093	5.111
35	Mean height of mercury in manometer, in atmospheres	0.5482	0.5462
36	Mean height of water in syphon draught gauge, in inches	0.3325	0.2421
37	Mean temperature of dew point, by calculation	59°.78	53°.23
38	Mean gain of temperature by the air, before reaching grate	217°.03	129°.41
39	Mean difference between steam and escaping gases	21°.7	38°.26
40	Water to 1 of coke, corrected for temp. of water in cistern	7.0575	7.6643
41	Water to 1 of coke, from 212°, corrected for temperature of water in cistern	7.9894	8.7038
42	Pounds of water, from 212°, to 1 cubic foot of coke	372.8	396.11
43	Water, from 212°, to 1 pound of combustible matter of the fuel	9.9494	10.4296
44	Mean pressure, in atmospheres, above a vacuum	1.4384	1.4365
45	Mean pressure, in pounds per sq. inch, above atmosphere	6,4739	6.4462
46	Condition of the air plates at the furnace bridge	Closed.	Open.
47	Inches opening of damper, (U. upper, L. lower)	U. 10	U. 10

TABLES XL, XLI, XLII, XLIII.

natural coke.

3d Trial. (Table XLII.)	4th Trial. (Table XLIII.)	Averages.	Remarks.
June 20.	*June* 21.		
24.333	25.0		
6.25	7.166		
14.07	14.07		
377.5	377.5		
18.75	18.75		
12.0	12.0		
1146.25	1121.0		
1085.25	1078.0		
61.0	43.0	43.6875	In the third trial, with the upper damper drawn but 5 inches, and the air plates open, the coke unburnt is 61 lbs.; while with the damper drawn 10 inches, and air plates closed, the quantity is but 31.75 lbs.
47.7604	46.7083	46.6602	
107.44	103.091	114.74	
7.6361	7.327	8.1538	
20.55	16.971	18.461	
4.838	5.3535	5.3134	
23.517	31.418	29.2355	
8284.0	8338.0		
74°.7	75°.4		
[illegible]	587.0		
77.0	76.0		
831.68	782.501	785.275	
13.307	12.52	12.562	
2.203	2.073	2.08	
2.177	2.114		
7.583	7.664	7.504	
7.741	7.59	6.958	
8.265	8.155	8.3373	
77°.58	79°.53		
65°.05	65°.59		
263°.44	292°.7	264°.03	
279°.33	271°.35	268°.302	
230°.9	230°.23		
76°.0	77°.0		
20.349	30.26		
5.1272	5.145		
0.545	0.5433		
0.2654	0.260	0.275	
58°.45	59°.0		
185°.91	213°.17	186°.38	
55°.23	45°.29	40°.12	
7.5387	7.6404	7.4752	
8.5414	8.6566	8.4728	
407.94	404.33	395.295	
10.7507	10.426	10.389	
1.4822	1.4809	1.4345	
6.383	6.3634	6.4166	
Open. U. 5	Closed. U. 5	–	The opening of the air plates appears, from the 43d line, to have produced a beneficial effect, whether the damper was drawn to the distance of 10, or only to that of 5 inches.

No. 10.

Artificial coke from Midlothian coal, procured for use in the navy yard.

This fuel was produced by coking in a pile, on an open coke hearth, at the navy yard, 16,190 pounds of coarse, and 6,090 pounds of fine Midlothian coal; the latter being used as a covering for the former, which was piled loosely together, in an oblong pile 15 or 20 feet long, 6 feet wide, and 4½ high, with suitable air passages leading to chimneys formed at three points in the length of the heap. The coking process was conducted slowly, lasting fifteen days. This was intended to avoid the waste of any portion of fixed carbon, and to yield a coke which, though it would undergo no further change of form while in combustion, would still give a flame of some activity.

From the above amount of 22,280 pounds of coal, there were derived 14,045 pounds of coarse and 3,870 pounds of fine coke. Had the coarse coke been to the whole weight only in proportion as the coarse coal was to its whole weight, there would have been 13,018 pounds in the coarse state. This proves that 1,017 pounds of coarse coke had been produced out of the fine portion of the coal. The loss of weight on the whole was 4,265 pounds, or 19.14 per cent. The finer portion round the edges of the heap, and some few lumps near its exterior, had of course escaped in part the full effect of the coking. But the purpose had been completely attained, producing a fuel of great strength and activity, and adapted to purposes for which the coal out of which it was formed would be inadmissible. During the coking, a considerable quantity of tarry matter, with some sulphur and other products of the distillation going on within the heap, were condensed about the chinks of the clay covering placed on the exterior. Flame was perceived but for a short time during the operation; and I am inclined to think that as much economy in conducting the process was observed as would be found practicable with coal of this character.

The weight per cubic foot of this coke, as determined by sixteen trials, was 32.734 pounds. The average weight of Midlothian "*screened*" coal was found to be 45.722 pounds; that of the "*average*" 54.044 pounds; and as the coarse and fine portions employed to form the coke were respectively 72⅔ and 27⅓ per cent., if the weights in a cubic foot of the mixture employed be assumed to have been proportionate to these numbers, then will the *coarse* coal in a cubic foot be $0.7266 \times 45.722 = 33.224$ pounds; that of fine, $0.2733 \times 54.044 = 14.806$ pounds; which makes the cubic foot 48.03 pounds; deducting 19.14 per cent., there are left 38.837 pounds; and from this, taking the weight of a cubic foot of coke, 32.734 pounds, there is left 6.103 pounds. Hence the enlargement of the bulk by coking was $6.103 \div 32.734 = 18.369$ per cent.

The space required for stowing 1 ton is 68.495 cubic feet. The coke lay some time on the ground after being raked from the heap, and a rain fell, which caused a complete saturation with moisture; 20 pounds lost by two days' exposure in the drying apparatus 9 ounces, or 2.81 per cent.

The total weight burned was 1,037 pounds; and the weight of ashes withdrawn (exclusive of those from wood) was 61.82 pounds; that of clinker 109.75 pounds. Hence the total waste is $171.57 \div 10.37 = 16.545$ per cent. of the coke actually burned.

From the Midlothian screened coal, the total waste was 10.31 per cent.; and from the average coal of the same mines, 14.82 per cent. Hence the waste (ashes and clinker) from 100 of the mixture of these two, formed as was that which was subjected to coking, would have amounted to 13.567. As the coal lost 19.14 per cent. in coking, the remaining 80.86 parts by weight of coke had also 13.567 parts of earthy matter, which is 16.778 per cent. One pound of soot and dust was procured from the flues after burning this coke.

It took two hours to bring the boiler into steady action, from the time the charging with coke commenced. When once ignited, it burns with great freedom and rapidity.

Upon a comparison of evaporative powers, after making in both cases the proper deductions for earthy matter, it will be found that this coke gave 10.343, and the screened and average Midlothian *coal* 9.85 pounds of steam from water at 212° to 1 of combustible matter. This proves that the fixed carbon contained in this coke had, weight for weight, a higher evaporative power than the volatile ingredients of the coal which had been expelled in coking. The superiority of the *coke combustible* over the *coal combustible* is 5.005 per cent. of the evaporative power of the latter.

From the column of "remarks" in the following table, it will be observed that it became necessary in the course of the experiment to withdraw from the furnace a quantity of clinker, in order to allow the combustion to proceed with regularity.

TABLE XLV.—COKE OF

Upper damper 8 inches open; air plates closed; steam

											Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coke.
Nov. 6	6.00	36	32	96	120	[illegible]	186	35	30.29	[illegible]	6.78	0.14	–	–
	9.00	38	34	110	238	[illegible]	231	[illegible]	30.32	[illegible]	4.86	0.31	–	53.75
	9.30	37	33	122	266	42	230	37	30.32	0.561	4.76	[illegible]	651	65.50
	10.00	38	34	130	295	[illegible]	232	[illegible]	30.33	[illegible]	4.62	[illegible]	651	67.50
														67.50
	10.30	41	38	141	304	39	232	39	30.32	[illegible]	[illegible]	[illegible]	651	56.50
														69.25
	11.00	43	40	154	304	39	235	40	30.30	0.566	4.70	0.41	1760	–
	11.30	45	41	168	302	[illegible]	[illegible]	42	30.30	[illegible]	[illegible]	0.40	2216	[illegible]
														70.50
	P. M.													
	0.00	46	42	176	295	[illegible]	[illegible]	42	30.27	[illegible]	[illegible]	0.40	[illegible]	68.25
	0.30	48	[illegible]	186	312	39	234	43	30.26	[illegible]	4.71	0.46	3475	[illegible]
	1.00	50	[illegible]	200	298	39	[illegible]	44	[illegible]	0.589	4.70	[illegible]	3874	66.75
	[illegible]	51	45	210	300	40	[illegible]	45	[illegible]	[illegible]	4.80	0.33	4456	68.00
	1.50	–	–	–	–	–	–	–	–	–	–	–	5150	65.50
	[illegible]	51	44	265	314	45	237	47	30.28	0.592	[illegible]	[illegible]	5150	60.00
	3.00	[illegible]	46	242	316	[illegible]	235	48	[illegible]	[illegible]	[illegible]	[illegible]	5942	62.25
	[illegible]	54	[illegible]	246	311	[illegible]	235	[illegible]	[illegible]	0.570	4.88	[illegible]	[illegible]	62.50
	[illegible]	54	47	252	[illegible]	46	231	[illegible]	[illegible]	0.582	4.75	[illegible]	6747	–
	4.40	50	43	266	270	45	234	48	30.21	0.554	5.04	[illegible]	7169	–
	[illegible]	50	43	262	262	[illegible]	231	49	[illegible]	[illegible]	[illegible]	0.31	7305	–
	5.25	[illegible]	41	262	253	[illegible]	231	48	[illegible]	0.586	5.16	[illegible]	7565	–
	A. M.													
Nov. 7	6.16	42	39	154	176	46	206	42	[illegible]	0.373	6.83	0.18	7565	–
	6.42	42.5	39	152	174	46	206	42	30.02	0.373	6.83	0.16	7693	–

Period of steady action from 11*h.* 4*m.* a. m. to 3*h.* 26*m.* p. m.—4*h.* 22*m.*; coke supplied to grate during that time, 592.5 lbs.; water to boiler, 4,505 lbs.

MIDLOTHIAN COAL.

thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	-	51	—16	-	Commenced firing at 6*h.* 10*m.* a. m.
9.00	-	72	+ 7	-	Wood consumed, 382.25 lbs; commenced charging with coke; steam allowed to escape by removing extra weight at 9*h.* 10*m.* a. m.
9.12	17 6	85	36		
9.32	19.8	92	63	-	Damper reduced to 8 inches; filling tank.
10.02	-	-	-	1.961	
10.15	30.3	100	72	-	Tank filled; water in boiler 1.5 inch below normal level; steam allowed to escape from back valve; morning clear; wind NW., light.
10.36	-	-	-		
-	33.2	111	69		
11.04	32.5	123	65	2.940	Commenced drawing gases at 11*h.* 52*m.* a. m.; fire in good action; drew in 50.5 minutes 100 cubic inches, which gave of water, 0.56 grain; carbonic acid, 7.44 grains; and oxygen, 9.167 cubic inches.
11.31					
11.51	34.0	132	59	3.158	
0.15	29 7	140	78	2.983	Wind SW., light.
0.50	29.5	150	61	2.114	Wind W., brisk.
1.30	35.0	159	64	3.052	Clinker removed from grate; commenced filling tank at 1*h.* 50*m.* p. m., concluded at 2*h.* 40*m.* p. m.
1.49					
2.06	31.4	214	77	3.709	
2.40	34.8	189	81	2.098 2.098	Twenty pounds of this coke was placed in drying apparatus. The number in the last column is here repeated, because the period is a full hour.
3.26	39.6	192	76	2.569	
-	36.6	198	70	1.695	Contents of ash pit thrown on grate; damper reduced to 3 inches.
-	29.5	216	36	1.756	Small weights removed from valves.
-	29.5	212	31	1.080	
-	27.9	215	22	-	Water in boiler left at 0.4 inch above normal level; weather becoming cloudy.
-	31.8	112	—30	-	Water in boiler found at 0.75 inch below normal level.
-	30.0	109.5	—32	-	Water in boiler adjusted

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	109.75
Ashes - - - - - - - - - -	61.75
Ashes behind bridge - - - - - - - - -	1.25
Total clinker and ashes - - - - - - - -	172.75
Deduct wood ashes - - - - - - - - -	1.173
Total waste from coal - - - - - - - -	171.577
Coke - - - - - - - - - -	9.5
Soot and dust - - - - - - - - - -	1.

TABLE XLVI.—DEDUCTIONS FROM TABLE XLV.

Experiments on coke of Midlothian coal.

	Nature of the data furnished by the preceding table.	Trial. (*Table XLV.*)
		Nov. 6.
1	Total duration of the experiment, in hours	24.7
2	Duration of steady action, in hours	4.367
3	Area of grate, in square feet	14.07
4	Area of heated surface of boiler, in square feet	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75
6	Number of charges of coke supplied to grate	16.0
7	Total weight of coke supplied to grate, in pounds	1046.5
8	Pounds of coke actually consumed	1037.0
9	Pounds of coke withdrawn and separated after trial	9.5
10	Mean weight, in pounds, of one cubic foot of coke	32.734
11	Pounds of coke supplied per hour, during steady action	135.676
12	Pounds of coke per square foot of grate surface, per hour	9.643
13	Total waste, ashes and clinker, from 100 pounds of coke	16.545
14	Pounds of clinker alone, from 100 pounds of coke	10.514
15	Ratio of clinker to the total waste, per cent.	63.546
16	Total pounds of water supplied to the boiler	7693.0
17	Mean temperature of water, in degrees Fahrenheit	41°.2
18	Pounds of water supplied at the end of experiment, to restore level	126.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	19.0
20	Pounds of water evaporated per hour, during steady action	1031.6
21	Cubic feet of water per hour, during steady action	16.505
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.733
23	Pounds of water per square foot, by a mean of several observations	2.746
24	Water evaporated by one of coke, from initial temperature (a) final result	7.4029
25	Water evaporated by one of coke, from initial temp. (b) during steady action	7.603
26	Pounds of fuel evaporating one cubic foot of water	8.4426
27	Mean temperature of air entering below ash pit, during steady pressure	47°.0
28	Mean temperature of wet bulb thermometer, during steady pressure	41°.61
29	Mean temperature of air, on arriving at the grate	192°.0
30	Mean temperature of gases, when arriving at the chimney	301°.38
31	Mean temperature of steam in the boiler	234°.38
32	Mean temperature of attached thermometer	43°.06
33	Mean height of barometer, in inches	30.271
34	Mean number of volumes of air in manometer	4.7254
35	Mean height of mercury in manometer	0.5863
36	Mean height of water in syphon draught gauge, in inches	0.3733
37	Mean temperature of dew point, by calculation	31°.08
38	Mean gain of temperature by the air, before reaching grate	145°.0
39	Mean difference between steam and escaping gases	70°.11
40	Water to one of coke, corrected for temperature of water in cistern	7.4029
41	Water to one of coke, from 212°, corrected for temperature of water in cistern	8.6319
42	Pounds of water, from 212°, to one cubic foot of coke	282.56
43	Water, from 212°, to one pound of combustible matter of the coke	10.3432
44	Mean pressure, in atmospheres, above a vacuum	1.4924
45	Mean pressure, in pounds per square inch, above atmosphere	7.2727
46	Condition of the air plates at the furnace bridge	Closed.
47	Inches opening of damper	Upper 8.

REMARKS.—This coke will be observed to give a greater rapidity of evaporation than most of the coals tried during these experiments. The porousness of coke, and the compactness of anthracite, place them in strong contrast in regard to facility of combustion, and justify the preference of the former fuel for locomotive engines; while its bulkiness precludes its adoption for sea steamers.

The great activity of this fuel rendered it necessary to load the valves with extra weights, to obviate foaming, and discharge of water mechanically mixed with the steam.

No. 11.

Artificial coke from Neff's Cumberland coal.

The coke on which this experiment was made was part of a quantity produced under my direction from a portion of the same boat load of coal from which the sample of Neff's coal, hereafter to be described, had been taken. It had lain for several weeks in the yard, and was doubtless, when taken to the coking hearth, quite as fully saturated with moisture as the sample tried for evaporative power. By reference to the description of that coal, it will be seen that, in the drying apparatus connected with the boiler, it lost 2.455 per cent.

The coke heap was composed of 22,340 pounds of coarse and 6,160 pounds of fine coal.

After coking for ten days, it was drawn, and, without being exposed to any rain, was carried while yet moderately warm, reweighed, and housed.

The quantity burned under the boiler was taken immediately to the building containing the apparatus, and was used on the following day.

This statement may indicate that the coke contained the minimum of moisture—contrary to what happened in the case of the coke from Midlothian coal, which contained, as proved on trial, 2.812 per cent. of moisture.

The weight of coarse coke from the above quantity of coal was 16,770 pounds, and the fine 6,805. Hence the weight of coarse coke is 75.065 per cent. of the coarse coal; while the *whole weight* of coke is of the whole weight of coal, both coarse and fine, 82.719 per cent.—showing a loss of 17.281 per cent., and proving that the disintegration of the coarse, rather than the agglutination of the fine portions of the coal, was the effect of the coking. The contrary has been shown to take place with the Virginia Midlothian coal.

By reference to the accompanying table of the experiment, and to that of deductions, it will be observed that the coke weighed at the rate of 31.57 pounds per cubic foot; while the average weight of the coal from which it was formed will hereafter appear to have been 54.287 pounds per cubic foot. Hence the loss by coking, of 17.281 per cent., will leave 44.907 pounds of coke from one cubic foot of raw coal. It follows, that the enlargement of bulk has been 42.25 per cent.

From the account hereafter to be presented, it will appear that the total waste, in ashes, clinker, and fine coke, from Neff's *coal*, was, on an average of four trials, 10.956 per cent.; while from the *coke* it was 13.515. The difference, 2.559, is 18.934 per cent. of the latter number, and indicates the ratio of loss in weight which the coal sustained in coking; but, as this is greater than 17.281, obtained by weighing the coke, we may infer that more unburnt matter passed through the grate while burning the coke, than had escaped while the coal was under trial. The difference is 1⅔ per cent.

It appears that, during steady action, the draught gauge, when using *coal*, with air plate closed and damper drawn 8 inches, stood at an average height of 0.388 inch, burning 126.6 pounds of coal per hour, and evaporating 1,060 pounds of water per hour; and that when using coke with a like arrangement of damper and air plate, the gauge marking 0.361 inch, the weight of coke burned per hour was 118.5 pounds, and

the water evaporated was 932 pounds per hour. Hence we have 126.6 : 118.5 :: 0.388 : 0.363; proving that the amount of combustion was very nearly proportioned on the two occasions to the force of the draught; while 0.388 : 0.361 :: 1,060 : 985, which proves that the evaporation was 53 pounds per hour less rapid with the coke than with the coal, even supposing the draught of the chimney to have been the same in both cases. The cause of more active draught during the day on which the coal was burned may probably have been the prevalence of a northwesterly wind, which generally, from the position of the building containing the apparatus, was observed to augment sensibly the force of the draught.

On comparing the evaporative power of the pound of coke with that of the same weight of Neff's coal, it will be observed that the latter was 9.742, and the former 8.997. As the *waste* from coal was, on the day of the first trial alluded to, 11.792 per cent., and 13.515 for the coke, the evaporative power in the unit of combustible matter in *coal* is 11.044, and in coke 10.381. Thus it appears that the combustible matter in the coke is 5.8 per cent. less effective, pound for pound, than that in the coal.

The comparison of this coke with that from Midlothian coal and with the natural coke will make it evident that the evaporative power of the combustible matter in each was almost exactly the same—being 10.381 for Neff's Cumberland coke, 10.343 for Midlothian coke, and 10.389 for natural coke. But while, as just seen, the coke of Cumberland coal is 5.8 *less* effective in its combustible constituents than the coal, in the Midlothian the reverse is true; the coke is 5.005 per cent. *more* efficient in the action of its combustible part than the original coal is in that of its compound of fixed and volatile combustibles. The time required by this coke to bring the boiler to steady action was 1.166 hour.

In the preceding article it has been seen that the Midlothian coal lost of its weight in coking 19.14 per cent., and gained in bulk 18.37 per cent. And as it was found that, when submitted to rapid distillation in a close vessel, specimens of the coal from which it was produced lost about 30.2 per cent., it is evident that of this quantity there remained in the coke 11.06 parts. If the water proved to have been imbibed by the coke (2,81 per cent. of its weight) be added to the apparent diminution by coking, it will give 21.41 per cent. as the quantity of volatile matter expelled, leaving only 8.79 parts remaining in the coke when first raked from the heap. This is but little more than two-thirds as much as in the natural coke already described, which, by an average of seven trials, contained 12.86 per cent. of volatile matter. As above stated, the Cumberland coal lost of its *weight* 17.28 per cent., and gained in *bulk* no less than 42.25 per cent.

The above results, which were obtained by working on a practical scale, may be compared with those which are known to be realized in practice by the different modes of coking adopted in the arts.

1. By coking in uncovered heaps of coarse lumps, (as at many of the iron works in Great Britain, France, and elsewhere,) and only covering up the ignited mass when flame ceases to be emitted. By this process, the loss in weight at Plymouth is stated to be 17, at Penn-y-darran 20, and at Dowlais 34 per cent.* This last is, no doubt, far greater than is

* See Mr. J. H. Alexander's Report on the Manufacture of Iron.

necessary, owing to the cheapness of coal, and the consequent neglect of economy in the management of the coking process. The coals at Dowlais and at Penn-y-darran bear a strong analogy to that of Cumberland, but have rather less volatile matter. Highly bituminous coals, coked in uncovered heaps, lose from 55 to 60 per cent. of their weight, and those of medium quality from 45 to 50, and those of still lower bituminousness from 30 to 40 per cent.* In all these cases, a considerable loss occurs from burning away some portion of the solid carbon on the exterior of the heap, before the slack and cinders are placed upon the coke to extinguish the fire.

2. By coking in stacks, (that is, in well-covered heaps of coal from 10 to 15 feet in diameter,) as followed in Staffordshire, coals of high bituminousness lose from 50 to 55, and those of a drier nature from 35 to 40 per cent.

3. By coking in close ovens, the coal of Rive-de-Gier yields 69 per cent. of coke, whereas by the first of the above methods it gives but 45 or 50. In the close oven, the *gain* of bulk is from 22 to 23 per cent. In the close oven, highly bituminous coals yield from 65 to 66 per cent.; but in the open heap only from 40 to 45, and this with an actual diminution of bulk.†

4. By coking in gas retorts, the Deane coal of Cumberland (England) gains in bulk nearly 30 per cent., and loses in weight 25 per cent.; Carlisle coal nearly the same; while Cannel and Cardiff coals gain in bulk 20, and lose in weight 36.5 per cent. Bewick's Wallsend coal loses 30, and Russell's Wallsend 30.7 per cent. by the same process.‡

Other important particulars, in relation to this material, will be found ranged under the proper heads in the general synoptical table of deductions following this class of coals.

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* See Leblanc & Walter *Métallurgie*, Pratique du Fer, p. 36.
† See Leblanc & Walter *Métallurgie*, Pratique du Fer, p. 47.
‡ Ure's Dictionory of Arts, article *Gas-light*.

TABLE XLVII.—COKE

Upper damper 8 inches open; air plates closed; steam

Date.	Hour.							Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coke.
	h. m. A. M.													
Oct. 21	5.10	60	56	86	–	62	73.25	60	[illegible]	[illegible]	6.97	0.07	–	–
	9.20	66	60	142	250	62	[illegible]	62	29.94	0.563	4.95	0.26	–	53.25
	9.50	67	[illegible]	158	260	62	231	63	[illegible]	[illegible]	5.14	0.35	317	50.25
	10.10	–	–	–	–	62	–	–	–	–	–	–	570	60.25
	10.30	69	61	[illegible]	270	[illegible]	234	65	29.91	[illegible]	5.04	0.37	737	59.00
	11.00	71	63	182	[illegible]	60	234	66	29.91	0.560	4.98	0.44	1172	70.25
	11.30	72	64	195	278	60	234	68	29.90	0.544	5.12	0.36	[illegible]	67.50
	P. M. 0.00	74	65	212	286	60	234	69	29.88	[illegible]	5.12	0.37	2092	56.25
	0.30	76	66	219	280	60	[illegible]	71	29.88	0.548	5.14	0.33	2518	57.00
	1.00	78	66	230	280	60	233	72	29.87	0.531	5.26	0.32	3112	68.25
	1.30	78	[illegible]	240	284	60	234	72.5	29.84	0.543	5.14	0.35	3534	61.00
	2.00	79	67	252	288	60	233	74	29.83	0.541	5.16	0.37	4022	60.50
	2.30	80	67.5	258	286	61	[illegible]	74	29.83	0.536	5.20	0.35	4257	64.75
	3.00	80	67	264	283	63	233	75	29.82	0.544	5.12	0.38	[illegible]	64.50
	[illegible]	80	68	270	292	63	[illegible]	75	[illegible]	0.543	5.14	0.37	5434	68.75
	[illegible]	80	68	284	266	66	233	75	29.81	0.535	5.22	0.33	6329	73.50
	5.00	80	69	282	266	66	233	75	29.80	0.530	5.26	0.30	6734	66.25
	5.15	79	67	298	[illegible]	66	231	75	29.80	0.510	5.48	0.26	7044	–
	7.15	76	64.5	295	225	[illegible]	231	72	29.81	0.519	5.38	0.24	[illegible]	–
	7.35	75.5	65	[illegible]	218	66	230	[illegible]	29.81	0.510	5.47	0.22	7449	–
Oct. 22	A. M. 5.30	67	60	200	196	66	228	66	29.71	0.503	5.53	0.18	7449	–
	6.15	67	[illegible]	197	194	66	225	66	29.70	0.456	6.00	0.18	7866	–

The period of steady action is from 10*h*. 35*m*. a. m. to 4*h*. 33*m*. p. m. =5*h*. 58*m*.; coke supplied to grate, 707.25 lbs.; water to boiler, 5,560 lbs.; hence, water to 1 of coke, 7.861.

OF NEFF'S COAL.

thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature of the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Water 0.15 inch below normal level.
-	52.4	28	-	-	Lighted fire in small furnace after set of observations; commenced firing at 5*h*. 48*m*.
9.20	55.7	76	+20	-	Wood consumed, 581.75 lbs.; commenced charging with coke.
9.42	55.9	94	29	1.679	Steam allowed to blow off at 9*h*. 40*m*.; damper set at 8 inches at 9*h*. 54*m*.
9.57					
10.12	55.6	99	36	1.669	
10.35	58.1	111	40	2.305	
11.14	59.3	123	44	2.183	Wind SW., brisk; clear; filled tank at 10*h*. 33*m*. a. m.; steam allowed to escape at back valve.
11.46	60.1	138	52	2.665	
0.11	60.8	143	46	2.257	
0.59	59.8	152	47	3.147	
1.33	61.6	162	50	2.235	
1.53	61.1	173	55	2.585	
2.27	61.5	178	52	1.245	
2.50	60.7	181	50	3.078	
3.20	62.4	190	58	3.158	
3.48	62.4	204	33	2.371	
4.33	62.4	202	35	2.146	Contents of ash pit thrown on grate.
-	61.1	219	13	-	Water in boiler left at 0.75 inch above normal level.
-	58.1	219	—6	-	Water 0.7 inch below normal level; closed damper to 4 inches.
-	59.3	214.5	—12	-	Water in boiler left at 0.18 inch above normal level; back valve double weighted.
-	55.0	133	—32	-	Water found 1.03 inch below normal level; some fire on grate.
-	56.9	130	—31	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	35.75
Ashes	94.50
Ashes behind bridge	4.125
Total clinker and ashes	134.375
Deduct wood ashes	1.749
Total waste of coke	132.626
Coke	16.00
Soot and dust	1.50

TABLE XLVIII.—DEDUCTIONS FROM TABLE XLVII.

Experiments on coke of Neff's coal.

	Nature of the data furnished by the preceding table.	Trial. (*Table XLVII.*)
		October 21.
1	Total duration of the experiment, in hours	25.133
2	Duration of steady action, in hours	5.966
3	Area of grate, in square feet	14.07
4	Area of heated surface of boiler, in square feet	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75
6	Number of charges of coke supplied to grate	16.0
7	Total weight of coke supplied to grate, in pounds	1010.25
8	Pounds of coke actually consumed	994.25
9	Pounds of coke withdrawn and separated after trial	16.0
10	Mean weight, in pounds, of one cubic foot of coke	31.5703
11	Pounds of coke supplied per hour, during steady action	118.547
12	Pounds of coke per square foot of grate surface, per hour	8.427
13	Total waste, ashes and clinker, from 100 pounds of coke	13.515
14	Pounds of clinker alone, from 100 pounds of coke	3.5504
15	Ratio of clinker to the total waste, per cent.	26.6234
16	Total pounds of water supplied to the boiler	7866.0
17	Mean temperature of water, in degrees Fahrenheit	62°.0
18	Pounds of water supplied at the end of experiment, to restore level	417.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	58.0
20	Pounds of water evaporated per hour, during steady action	931.947
21	Cubic feet of water per hour, during steady action	14.911
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.469
23	Pounds of water per square foot, by a mean of several observations	2.475
24	Water evaporated by 1 of coke, from initial temperature (a) final result	7.853
25	Water evaporated by 1 of coke, from initial temp. (b) during steady action	7.861
26	Pounds of fuel evaporating one cubic foot of water	7.9588
27	Mean temperature of air entering below ash pit, during steady pressure	75°.0
28	Mean temperature of wet bulb thermometer, during steady pressure	65°.0
29	Mean temperature of air, on arriving at the grate	219°.57
30	Mean temperature of gases, when arriving at the chimney	276°.93
31	Mean temperature of steam in the boiler	238°.21
32	Mean temperature of attached thermometer	70°.36
33	Mean height of barometer, in inches	29.876
34	Mean number of volumes of air in manometer	5.124
35	Mean height of mercury in manometer	0.5445
36	Mean height of water in syphon draught gauge, in inches	0.3609
37	Mean temperature of dew point, by calculation	59°.64
38	Mean gain of temperature by the air, before reaching grate	144°.57
39	Mean difference between steam and escaping gases	47.91
40	Water to 1 of coke, corrected for temperature of water in cistern	7.853
41	Water to 1 of coke, from 212°, corrected for temperature of water in cistern	8.9966
42	Pounds of water, from 212°, to 1 cubic foot of coke	*284.02
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.3811
44	Mean pressure, in atmospheres, above a vacuum	1.4256
45	Mean pressure, in pounds per square inch, above atmosphere	6.2852
46	Condition of the air plates at the furnace bridge	Closed.
47	Inches opening of damper	Upper 8.

* It will be seen, by a comparison of this number with one of the results of Beaver Meadow anthracite No. 5, that, bulk for bulk, this artificial coke is very nearly half as efficient as the anthracite.

No. 12.

Mixture of Beaver Meadow anthracite and Midlothian bituminous coal.

The mixture here referred to was, in the first trial, composed of two charges, or 4 cubic feet, weighing 218 pounds of average Midlothian coal, and eight charges, or 16 cubic feet, of the same sample of Beaver Meadow anthracite from the navy yard, on which some experiments have already been detailed, weighing 870 pounds; making in all 1,088 pounds of mixture.

In the second trial, the two charges of Midlothian coal weighed 217.75 pounds; and the eight charges of Beaver Meadow anthracite 866 pounds; or the mixture was 1,083.75 pounds. The anthracite was in lumps of about 4 inches in diameter.

The use of this bituminous coal does not appear to have greatly accelerated the action of the anthracite; though, in both trials, a charge of the latter was laid upon the grate before the fire of wood was commenced. From the time when the wood was withdrawn to that when the boiler was in steady action in the first trial, the period elapsed was three hours and fifty minutes; and, in the second trial, it was two hours and thirty-five minutes. By a reference to the table of deductions, it appears that the weight of water, from 212°, to 1 of the mixed fuel burned, was 8.86; while, from table XXXIX, it appears that the same anthracite alone gave 9.079 pounds of steam to 1 of anthracite. The sample of "Midlothian average" coal gave 8.29, as will be seen on referring to column 16 of table CXCVIII, and to line 41 of averages, table CXXXVII, in subsequent parts of this report.

It will be remarked that all the trials on mixtures were made in the earlier periods of experimenting, when the chimney was but 41 feet high, and the draught was consequently much inferior to what it afterwards became by the addition of 22 feet. But they are still comparable with each other.

TABLE XLIX.—MIXED COALS—ONE-FIFTH MIDLOTHIAN

First trial—upper damper 12

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
April 17	7.35	59	-	108	140	60	163	-	29.86	-	-	0.08	-	108.75
	9.30	64	-	116	280	60	192	-	29.86	-	-	0.15	-	-
	10.25	68	-	126	230	60	226	-	29.87	0.159	9.00	0.18	-	108.25
	11.00	68	-	136	222	60	228	-	29.87	0.163	8.96	0.19	-	109.25
	P. M.													
	0.00	69.5	-	148	238	58	228	-	29.88	0.166	8.94	0.20	500	108.25
	0.30	69.25	-	156	258	58	229	-	29.87	0.173	8.86	0.20	590	108.25
	1.30	69.5	-	172	250	57	229	-	29.87	0.175	8.84	0.20	640	109.25
	2.15	69	-	200	252	58	229	-	29.87	0.181	8.78	0.20	870	109.25
	3.15	69.5	-	250	236	58	229	-	29.86	0.173	8.86	0.20	1580	-
	4.00	69.5	-	290	260	58	229	-	29.88	0.179	8.80	0.18	2270	109.25
	4.40	68.5	-	324	260	58	229	-	29.85	0.183	8.7[illegible]	0.22	2770	109.25
	5.15	68	-	360	278	58	229	-	29.87	0.180	8.79	0.21	3370	-
	6.00	66	-	370	276	58	228	-	29.85	0.179	8.80	0.22	3525	-
	6.40	66.5	-	375	282	58	228	-	29.85	0.183	8.76	0.22	4380	109.25
	8.30	63	-	320	305	60	230	-	29.85	0.196	8.66	0.30	5205	-
	9.15	-	-	-	-	-	-	-	-	-	-	-	6735	-
	A. M.													
April 18	6.30	51	-	190	176	62	210	-	29.92	-	-	0.13	8024	-

Period of steady action, from 2*h.* 15*m.* to 7*h.* p. m.=4*h.* 45*m.*; coal supplied to the grate, 327.75 lbs.; water to boiler, 2,810 lbs.

BITUMINOUS, AND FOUR-FIFTHS BEAVER MEADOW ANTHRACITE.

inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
7.35	-	49	—23	-	Commenced firing; first charge of anthracite thrown on behind wood; combustion with lower damper open; wood consumed, 302¾ lbs.; steam begins to blow off; lower damper closed, and upper opened; smoke from chimney; grate well charged; filled tank at 11*h*. 35*m*. The anthracite (except the first charge) and the bituminous coal were mixed on the platform, before being thrown on the grate.
-	-	52	+88		
10.25	-	58	4		
10.40	-	68	— 6		
11.00	-	78.5	+10	0.572	
0.30	-	86.75	29	1.324	
1.30	-	102.5	21	0.397	
2.15	-	131	23	0.812	
....		....	....	....	
-	-	180.5	7	1.880	
4.00	-	220.5	31	2.475	
4.40	-	255.5	31	1.986	Filled tank at 4*h*. 45*m*.
-	-	292	49	2.724	
-	-	304	48	0.547	
7.00	-	309.5	54	3.417	
....		....	....	....	
-	-	257	75	1.213	
-	-	-	-	-	Fire declining rapidly, but steam still blows off.
-	-	139	—34	-	Water in the boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	52.00
Ashes - - - - - - - - - -	38.00
	90.00
Deduct wood ashes - - - - - - - - -	0.927
Total waste from coal - - - - - - - -	89.073
Coke - - - - - - - - - - -	64.75

TABLE L.—MIXED COALS—ONE-FIFTH MIDLOTHIAN

Second trial—upper damper 12

Date.	Hour.	Open air entering below ash pit.									Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
April 19	7.00	46.5	–	162	168	52	196	–	30.15	–	–	0.20	–	108.75
	9.15	47	–	[illegible]	240	52	226	–	30 15	0.169	8 90	0.21	–	–
	9.50	47	–	164	230	52	228	–	30.15	0.175	8.64	0.21	–	108.50
	10.40	48	–	154	237	52	228	–	30.16	0.185	8.74	0.21	–	108.50
	11.20	49	–	160	252	52	228	–	30.17	0.190	8.69	0.20	–	–
	11.50	49	–	164	262	52	228	–	30.17	[illegible]	[illegible]	0.22	250	108.50
	P. M.													
	0.20	49	–	172	272	52	228	–	30.16	[illegible]	8.54	0.22	[illegible]	–
	0.50	49.5	–	188	294	53	229	–	30.16	0.203	[illegible]	0.25	810	108.25
	1.50	50	–	230	288	52	230	–	30.16	0.210	[illegible]	0 25	1410	–
	2.20	50.5	–	249	298	53	230	–	30.16	0.217	8.42	0.26	1580	108.25
	3.20	51	–	270	284	54	230	–	30.16	0.210	8.48	0.26	2280	108.25
	4.00	51	–	298	277	53	230	–	30.16	0.206	8.52	0.26	3250	–
	4.30	51	–	310	268	[illegible]	230	–	30.16	[illegible]	8 56	0.26	3480	[illegible]
	5.00	51	–	320	266	[illegible]	230	–	30.16	0.200	8 58	0.25	3980	108.25
	6 00	50.5	–	350	306	53	230	–	30.15	0.210	[illegible]	0.25	4265	108.25
	6.30	50	–	360	306	53	229	–	30.15	0.212	[illegible]	0.25	4715	–
	6.50	–	–	–	–	–	–	–	–	–	–	–	5615	
	A. M.													
April 20	6.30	47.5	–	[illegible]	174	53	198	–	30.20	–	–	0.19	8295	–

Period of steady action, from 11*h.* 50*m.* a. m. to 6*h.* p. m.=6*h.* 10*m.*; coal supplied to the grate, 649.5 lbs.; water to the boiler, 4,015 lbs.

BITUMINOUS, AND FOUR-FIFTHS BEAVER MEADOW ANTHRACITE.

inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
7.00	-	115.5	—28	-	Commenced firing; first charge (all anthracite) thrown behind wood.
-	-	117	+14	-	Wood consumed, 214½ lbs.; steam at equilibrio; ash pit doors opened; ash pit doors closed; steam blowing off.
9.50	-	117	4		
10.40	-	106	9		
-	-	111	24		
11.50	-	115	34	0.257	
....		....	....	....	
-	-	123	44	2.145	
0.50	-	138.5	65	1.086	
-	-	180	58	1.589	
2.20	-	197.5	68	0.901	
3.20	-	219	54	1.854	
-	-	247	47	3.854	
4.30	-	259	38	1.218	
5.30	-	269	36	1.589	Filled tank at 5*h*. 30*m*.
6.00	-	299.5	76	0.753	
....		....	....	....	
-	-	310	77		
-	-	134.5	—24	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	49.50
Ashes	44.25
Total clinker and ashes	93.75
Deduct wood ashes	0.658
Total waste from coal	93.092
Coke	51.00

TABLE LI.—DEDUCTIONS

Experiments on mixed coal—one-fifth Midlothian bitu

	Nature of the data furnished by the respective tables.	1st Trial. (*Table XLIX.*)	2d Trial. (*Table L.*)
		April 17.	*April* 19.
1	Total duration of the experiment, in hours	22.916	23.5
2	Duration of steady action, in hours	4.75	6.166
3	Area of grate, in square feet	16.25	16.25
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.66	21.66
6	Number of charges of coal supplied to grate	10.0	10.0
7	Total weight of coal supplied to grate, in pounds	1088.0	1083.75
8	Pounds of coal actually consumed	1020.25	1029.75
9	Pounds of coal withdrawn and separated after trial	67.75	54.0
10	Mean weight, in pounds, of one cubic foot of coal	54.4	54.1875
11	Pounds of coal supplied per hour, during steady action	84.04	105.318
12	Pounds of coal per square foot of grate surface, per hour	5.171	6.481
13	Total waste, ashes and clinker, from 100 pounds of coal	8.7303	9.04
14	Pounds of clinker alone, from 100 pounds of coal	5.0552	4.7711
15	Ratio of clinker to the total waste, per cent.	57.819	52.812
16	Total pounds of water supplied to the boiler	8024.0	8295.0
17	Mean temperature of water, in degrees Fahrenheit	58°.0	52°.5
18	Pounds of water supplied at the end of experiment, to restore level	1289.0	2680.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	185.0	398.0
20	Pounds of water evaporated per hour, during steady action	826.15	651.04
21	Cubic feet of water per hour, during steady action	13.22	10.416
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.188	1.7246
23	Pounds of water per square foot, by a mean of several observations	2.178	2.665
24	Water evaporated by one of coal, from initial temperature (a) final result	7.683	7.668
25	Water evaporated by one of coal, from initial temperature (b) during steady action	8.543	6.181
26	Pounds of fuel evaporating one cubic foot of water	8.1348	8.1506
27	Mean temperature of air entering below ash pit, during steady pressure	68°.386	50°.35
28	Mean temp. of wet bulb thermometer, during steady pressure	–	–
29	Mean temperature of air, on arriving at the grate	252°.82	274°.6
30	Mean temperature of gases, when arriving at the chimney	255°.64	285°.9
31	Mean temperature of steam in the boiler	228°.64	229°.6
32	Mean temperature of attached thermometer	66°.0	48°.0
33	Mean height of barometer, in inches	29.865	30.158
34	Mean number of volumes of air in manometer	8.832	8.506
35	Mean height of mercury in manometer, in atmospheres	0.176	0.207
36	Mean height of water in syphon draught gauge, in inches	0.2166	0.2555
37	Mean temperature of dew point, by calculation.		
38	Mean gain of temperature by the air, before reaching grate	184°.434	224°.25
39	Mean difference between steam and escaping gases	27°.0	56°.3
40	Water to one of coal, corrected for temp. of water in cistern	7.7128	7.668
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	8.866	8.8554
42	Pounds of water, from 212°, to one cubic foot of coal	482.31	479.85
43	Water, from 212°, to one pound of combustible matter of the mixed fuel	9.7141	9.7355
44	Mean pressure, in atmospheres, above a vacuum	1.4192	1.4531
45	Mean pressure, in pounds per square inch, above atmosphere	6.1902	6.692
46	Condition of the air plates at the furnace bridge	Removed.	Removed.
47	Inches opening of damper, (U. upper)	U. 12	U. 12

FROM TABLES XLIX, L.

minous, and four-fifths Beaver Meadow anthracite.

Averages.	Remarks.
—	The period of steady action in the first trial is, perhaps, rather less than that here indicated. A good deal of uncertainty necessarily exists as to the relation between the quantity of coal on the grate and the water evaporated, at any assumed period of the experiments; and, consequently, in regard to the deductions dependent on those elements of the calculation.
60.875	
54.2937	
94.679	
5.826	
8.8851	
4.9132	
55.3155	
628.595	
11.818	
1.0652	
7.6755	
7.362	
8.1428	
—	No observations on the wet bulb thermometer were taken at the period of these experiments.
263°.71	
270°.77	
0.236	
204°.842	
41°.65	
[illegible].6904	
[illegible].8607	
481.08	
9.7848	The close approximation of the two numbers in this line intimates the degree of reliance which may be placed in the results for practical purposes.
1.4361	
6.4411	

No. 13.

Mixture of Beaver Meadow anthracite and Cumberland bituminous coal.

This mixture was, for the first trial, made up of 221.75 pounds of Cumberland coal, taken from a quantity in use in the navy yard, and 886.5 pounds of Beaver Meadow anthracite, of the same sample which has been referred to in preceding experiments.

In the second trial, the Cumberland coal weighed 204.5, and the anthracite 867.75 pounds. The moisture in the Cumberland coal was found by trial to be 2.12 per cent.

In each case a charge of anthracite was placed on the grate before kindling the fire with wood; the only advantage of which was, that a bed of warm anthracite was prepared, on which to commence firing with the mixed coal when the steam was up, and the wood had been withdrawn.

The mixture of these two coals appears, by a mean of the two trials, to have brought the boiler to steady action in two and a quarter hours, and therefore to have been greatly superior to the anthracite alone in this particular, as the latter took 5.08 hours for that purpose. By a reference to the table LIV of *deductions*, it will be seen that the steam from 212° to 1 of this mixed coal was, on an average, 9.18; while for this Beaver Meadow anthracite alone, it was 9.079. From this statement, it is evident that, by the mixture of coal of low bituminousness with the anthracite in question, a considerable increase of activity in the fire takes place, with an augmentation of the total evaporative power.

When a coal of high bituminousness, like the Midlothian of Virginia, is mixed with anthracite, the coking of the former material agglutinates together not only its own masses, but also those of the anthracite, covering up the surfaces of the latter, and preventing the easy access of air. For this reason, the fire becomes sluggish in its action; but, with a free-burning bituminous coal, like that of Cumberland, the lumps scarcely cohere together in coking, and still less do they adhere firmly to the anthracite. And, as the bituminous part of the mixture comes quickly to a state of ignition, it aids considerably the heating up of the anthracite to the temperature at which its combustion can commence. This accounts for the more prompt and vigorous action of the mixture now under consideration, than of that previously presented. Each ingredient of the mixture appears by the experiments to retain its distinct evaporative power; the Beaver Meadow anthracite alone being rather more efficacious than its mixture with Midlothian, and rather less so than that with the Cumberland coal.

It appears that on the first day's trial the mean weight of a cubic foot of the mixture was 55.412 pounds; but on the second only 53.612 pounds. The anthracite separately weighed 55.406 on the first day, and 54.812 on the second. This difference would be fully accounted for by supposing that the anthracite used on the first day was from the Beaver Meadow mine No. 5, and that employed on the second from slope No. 3; since, from the tables at pages 45 and 61, it appears that those two varieties differ from each other by rather less than 2 pounds per cubic foot; the former weighing the most, and possessing the highest evaporative power. From the table LIV of deductions, relative to the mixture now under considera-

tion, it likewise appears that the first experiment afforded a result in evaporative power, as seen in lines 40, 41, and 43, superior to that of the second; and this superiority amounts to about 2 per cent.—an amount very nearly agreeing with the superiority of the anthracite of slope No. 5 over that from No. 3.

It is worthy of notice, that on the second day's combustion the difference of temperature between the steam and the escaping gases was 9.5° greater than on the first day.

As to the rapidity of evaporation, line 21 of the table shows that on the first trial 13.37 cubic feet of water were supplied to the boiler per hour, and on the second 13.56; while, with the anthracite alone, it is seen, by table XXXIX, that the rate of evaporation with the same size of grate and the same height of chimney was but 11.142 cubic feet per hour when using the first variety of anthracite, and 7.709 for the second. Hence the average gain of activity by the mixed fuel over the anthracite is 4.04 cubic feet per hour, or nearly 43 per cent. By table LI, it appears that the average rate of evaporation by the mixture of anthracite and *Midlothian* coal was 11.818 cubic feet, and that the gain on the anthracite alone was, consequently, 2.393 cubic feet, or 20.5 per cent.

TABLE LII.—MIXED COALS—ONE-FIFTH

First trial—upper damper 8

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
April 15	6.30	-	-	-	-	55	135	-	-	-	-	-	-	107.75
	9.45	57	-	148	236	55	226	-	29.95	0.185	8.74	0.18	-	111.75
	10.25	58	-	160	246	54	229	-	29.96	0.189	8.70	0.21	160	113.25
	11.15	59	-	195	278	54	229	-	29.95	0.207	8.50	0.25	685	11[illegible].25
	11.45	59	-	212	300	53	230	-	29.95	0.201	8 48	0.30	860	107.00
	P. M.													
	0.45	62	-	288	360	54	230	-	29.94	0.195	8.64	0.25	1655	111.25
	1.30	63.5	-	308	272	55	230	-	29.93	0.183	8.76	0.25	2715	111.25
	2.00	64.5	-	312	260	56	229	-	29.93	0.193	8.66	0.25	3120	111.25
	2.40	65	-	304	270	56	230	-	29.92	0.195	8.64	0.26	3290	111.25
	3.30	65.5	-	310	296	56	230	-	29.92	0.205	8.54	0.26	3995	111.25
	4.15	65.5	-	320	292	56	230	-	29.92	0.205	8.54	0.28	4915	-
	4.45	65	-	330	280	56	230	-	29.91	0.197	8.61	0.28	5215	-
	5.45	65	-	318	280	56	230	-	29.92	0.185	8.74	0.27	6205	-
	6.40	-	-	-	-	54	-	-	-	-	-	-	7765	-
	A. M.													
April 16	7.00	55	-	156	180	57	206	-	29.96	-	-	0.12	8630	-

The period of steady action extends from 11*h.* 45*m.* a. m. to 3*h.* 30*m.* p. m. = 3*h.* 45*m.*; coal supplied to grate, 556.25 lbs ; water to boiler, 3,135 lbs.

CUMBERLAND AND FOUR-FIFTHS BEAVER MEADOW.

inches open; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam & escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
6.30	-	-	-	-	Commenced firing; first charge of coal thrown on behind wood.
9.45	-	91	+ 10	-	Wood consumed, 660¼ lbs.; steam blows off.
10.25	-	102	17	0 636	
11.15	-	136	44	1.605	
11.45	-	153	70	1.033	
....				....	
0.45	-	226	130	2.370	Temperature of escaping gases, taken at lower flue, 360°.
1.30	-	244.5	42	3.746	
2.00	-	247.5	31	2.145	
2.10	-	239	40	0.675	Filled tank at 2*h.* 45*m.*
2.30	-	244.5	66	2.241	No smoke from chimney to-day, after the fire was in good action.
....		....	....	....	
-	-	254.5	62	3.276	Placed 28 lbs. of the Cumberland coal (which was wet) in drying apparatus.
-	-	265	50	1.589	The combustion is abundantly rapid.
-	-	253	50	2.357	Filled tank at 5*h.* 50*m.*
-	-	-	-	-	Left a considerable bed of coal in good action on grate.
-	-	101	— 26	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	34.00
Ashes - - - - - - - - - - -	51.50
Total clinker and ashes - - - - - - - -	85.50
Deduct wood ashes - - - - - - - - -	2.024
Total waste from coal - - - - - - - -	83.476
Coke - - - - - - - - - - -	56.00

TABLE LIII.—MIXED COALS—ONE-FIFTH

Second trial—upper damper 8

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
April 18	8.00	-	-	-	-	56	190	-	-	-	-	-	-	112.50
	9.15	52	-	162	256	56	213	-	29.98	-	-	0.19	-	-
	10.30	52	-	174	240	56	226	-	30.01	0.169	8.90	0.20	-	106.25
	11.30	52	-	174	240	56	228	-	30.01	0.180	8.79	0.19	175	106.25
	P. M.													
	0.00	52	-	176	270	56	228	-	30.01	0.189	8.70	0.18	375	106.25
	1.00	52	-	202	290	56	229	-	30.01	0.203	8.56	0.22	825	106.25
	2.00	52	-	222	304	56	229	-	30.02	0.206	8.50	0.26	1875	-
	2.40	52	-	250	292	56	230	-	30.00	0.210	8.48	0.25	2585	107.00
	3.10	52	-	282	264	56	229	-	30.00	0.191	8.68	0.20	2835	107.00
	3.45	52	-	282	308	56	230	-	30.00	0.201	8.78	0.27	3640	-
	4.10	51.5	-	288	314	56	230	-	30.00	0.215	8.43	0.31	3925	107.00
	4.45	51	-	299	294	55	229	-	30.00	0.203	8.55	0.29	4410	-
	5.15	51	-	310	302	55	229	-	30.02	0.202	8.57	0.25	4740	107.00
	5.45	50.5	-	314	288	55	229	-	30 02	0.196	8.63	0.25	5065	-
	6.00	50.5	-	322	286	54	229	-	30.02	0.202	8.58	0.26	5065	106.75
	6.30	-	-	-	-	-	-	-	-	-	-	-	5975	
	7.40	49	-	310	284	55	229	-	30.05	0.200	8.59	0.28	5975	-
	8.00	-	-	-	-	-	-	-	-	-	-	-	6460	
	A. M.													
April 19	7.00	46.5	-	162	168	52	196	-	30.05	-	-	0.20	8306	-

Period of steady action, from 1*h.* to 6*h.* p. m. = 5 hours; coal supplied to grate, 534.75 lbs.; water to boiler, 4,240 lbs.

CUMBERLAND AND FOUR-FIFTHS BEAVER MEADOW.

inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
8.00	-	-	-	-	Commenced firing; first charge thrown on back of wood.
-	-	110	+43	-	Consumed 205 lbs. of wood.
10.30	-	122	14	-	Steam begins to blow off.
10.45	-	122	12	0.464	
0.00	-	124	42	1.059	Grate well covered with coal.
1.00	-	150	61	1.192	
....		....	....	....	
-	-	170	75	2.781	
2.40	-	198	62	2.821	
3.10	-	230	35	1.324	
-	-	230	78	3.655	Little or no smoke seen at chimney top to-day.
4.10	-	236.5	84	1.812	
-	-	248	65	2.201	Damper, for the last three hours, two thirds closed.
5.15	-	259	73	1.748	
-	-	263.5	59		
6.00	-	271.5	57	1.148	
....		....	....	....	
-	-	261	55		
-	-	115.5	—28	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	41.00
Ashes - - - - - - - - - -	45.75
	86.75
Deduct wood ashes - - - - - - - - -	0.715
Total waste from coal - - - - - - - -	86.035
Coke - - - - - - - - - -	47.5

TABLE LIV.—DEDUCTIONS

Experiments on mixed coal—one-fifth Cumberland

	Nature of the data furnished by the respective tables.	1st Trial. (*Table LII.*)	2d Trial. (*Table LIII.*)
		April 15.	*April* 18.
1	Total duration of the experiment, in hours	24.5	23.0
2	Duration of steady action, in hours	3.75	5.0
3	Area of grate, in square feet	16.25	16.25
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.66	21.66
6	Number of charges of coal supplied to grate	10.0	10.0
7	Total weight of coal supplied to grate, in pounds	1108.25	1072.25
8	Pounds of coal actually consumed	1052.25	1021.75
9	Pounds of coal withdrawn and separated after trial	56.0	50.5
10	Mean weight, in pounds, of one cubic foot of coal	55.4125	53.6125
11	Pounds of coal supplied per hour, during steady action	148.84	106.95
12	Pounds of coal per square foot of grate surface, per hour	9.128	6.5815
13	Total waste, ashes and clinker, from 100 pounds of coal	7.9328	8.4204
14	Pounds of clinker alone, from 100 pounds of coal	3.2312	2.943
15	Ratio of clinker to the total waste, per cent.	39.766	34.951
16	Total pounds of water supplied to the boiler	8630.0	8306.0
17	Mean temperature of water, in degrees Fahrenheit	54°.6	55°.5
18	Pounds of water supplied at the end of experiment, to restore level	1100.0	1841.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	158.0	273.0
20	Pounds of water evaporated per hour, during steady action	836.0	848.0
21	Cubic feet of water per hour, during steady action	13.37	13.56
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.214	2.246
23	Pounds of water per square foot, by a mean of several observations	1.9735	2.186
24	Water evaporated by one of coal, from initial temp. (a) final result	8.0703	7.862
25	Water evaporated by one of coal, from initial temp. (b) during steady action	5.636	7.946
26	Pounds of fuel evaporating one cubic foot of water	7.763	7.9497
27	Mean temperature of air entering below ash pit, during steady pressure	62°.91	51°.23
28	Mean temperature of wet bulb thermom., during steady pressure.		
29	Mean temperature of air, on arriving at the grate	277°.91	280°.09
30	Mean temperature of gases, when arriving at the chimney	284°.45	293°.27
31	Mean temperature of steam in the boiler	229°.91	229°.27
32	Mean temperature of attached thermometer	60.0	49°.0
33	Mean height of barometer, in inches	29.932	30.013
34	Mean number of volumes of air in manometer	8.619	8.577
35	Mean height of mercury in manometer, in atmospheres	0 196	0.205
36	Mean height water in syphon draught gauge, in inches	0.2644	0.26
37	Mean temperature of dew point, by calculation.		
38	Mean gain of temperature by air before reaching grate	215°.0	228°.86
39	Mean difference between steam and escaping gases	54°.54	64°.0
40	Water to one of coal, corrected for temperature of water in cistern	8.0703	7.862
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	9.3036	9 0566
42	Pounds of water, from 212°, to one cubic foot of coal	515.54	481.47
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	10.1052	9.8893
44	Mean pressure, in atmospheres, above a vacuum	1.4552	1.4433
45	Mean pressure, in pounds per square inch, above atmosphere	6.7227	6.5467
46	Condition of the air plates at the furnace bridge	Removed.	Removed.
47	Inches opening of damper, (U. upper)	U. 8.	U. 8.

FROM TABLES LII, LIII.

bituminous, and four-fifths Beaver Meadow anthracite.

Averages.	Remarks.
53.25	
54.5125	
127.645	The coal at the first trial appears to have been supplied more rapidly than it was consumed for a considerable part of the time, leaving a heavy bed upon the grate.
7.9847	
8.1766	
3.0871	
37.3585	
842.0	The errors liable to occur in the estimation of the water evaporated per hour during steady action, are much less than those which may exist in regard to the weight of coal actually consumed.
13.472	
2.23	
7.9662	
6.791	The time designated for the commencement of steady action, in the first trial, is obviously somewhat too early; an hour later might, with greater approach to certainty, have been assigned. At that time the sixth charge was on the grate.
7.8564	
278°.995	
288°.86	
0.2622	
221°.93	
59°.27	
7.9661	
9.1801	
498.505	The difference in this line between the two trials will be found accounted for, in a considerable measure, by the greater proportion of waste in the second than in the first trial.
9.9973	
1.4492	
6.6347	

TABLE LV.—*Synoptical table of the character, composition, and efficiency of the anthracites.*

Designation of coals.	Density.						Composition, in 100 parts.						
	Specific gravity.	Pounds per cubic foot, calculated from specific gravity.	Number of experiments, to determine actual weight.	Weight, in pounds per cubic foot, by experiment.	Ratio of actual to calculated weight.	Cubic feet of space required to stow one ton.	Moisture, determined by steam drying apparatus.	Volatile matter, other than moisture.	Sulphur.	Fixed carbon.	Coke.	Earthy matter.	Ratio of fixed to volatile combustible matter.
Beaver Meadow, slope No. 3 -	1.610	100.64	40	54.925	0.5457	40.783	1.562	2.381	0.011	88.912	96.052	7.112	37.308
Beaver Meadow, slope No. 5 -	1.551	96.93	40	56.194	0.5797	39.862	0.893	3.604	0.062	90.355	95.504	5.149	25.363
Forest Improvement - -	1.477	92.31	37	53.658	0.5812	41.746	1.785	3.050	0.016	90.751	95.165	4.411	29.754
Peach Mountain - - -	1.464	91.50	70	53.794	0.5878	41.640	1.897	2.958	0.006	89.020	95.145	6.125	30.095
Lehigh - - - -	1.590	99.39	36	55.316	0.5566	40.495	0.000	5.285	-	89.153	94.715	5.562	16.869
Lackawanna - - -	1.421	88.84	44	48.886	0.5502	45.820	2.120	3.793	0.123	87.741	94.087	6.346	23.132
Lyken's Valley - - -	1.389	86.82	26	48.558	0.5591	46.130	0.111	6.796	0.091	83.841	93.093	9.252	12.337
Beaver Meadow, (navy yard) -	-	-	19	55.539	-	40.650	-	-	-	-	-	8.104	
Natural coke of Virginia - -	1.323	82.69	47	46.635	0.5639	48.032	1.116	11.977	0.466	75.081	86.907	11.826	6.269
Coke of Millothian (Va.) coal -	-	-	16	32.703	-	68.495	2.812	-	-	-	-	16.545	
Coke of Neff's Cumberland (Md.) coal	-	-	16	31.570	-	70.953	-	-	-	-	-	13.340	
Mixture, one fifth Midlothian and four-fifths Beaver Meadow -	-	-	20	51.294	-	41.258	-	-	-	-	-	8.885	
Mixture, one-fifth Cumberland and four-fifths Beaver Meadow -	-	-	20	54.513	-	41.092	-	-	-	-	-	8.176	

SYNOPTICAL TABLE LV—Continued.

Designation of coals.	Combustion.				Action of furnace during steady pressure.					Evaporation.					
					Mean temperature.						Pressure.		Water supplied per hour during steady action.		
	Total No. of pounds consumed.	Pounds supplied per hour, during steady action.	Pounds per square foot of grate surface per hour, during steady action.	Pounds evaporating one cubic foot of water.	Of air, on arriving at grate.	Of gases, on arriving at chimney.	Gained by the air, before reaching grate.	Of escaping gases above that of steam in boiler.	Draught gauge—height in inches, of water.	Time required to bring boiler to steady action, in hours.	In atmospheres, above a vacuum.	In pounds per sq. inch, above 1 atmosphere.	In pounds.	In cubic feet.	In pounds per square foot of absorbing surface of boiler.
Beaver Meadow, slope No. 3 -	3944.50	94.146	6.691	7.595	238.46	254.00	150.75	23.03	0.330	3.866	1.418	6.171	785.94	12.572	2.082
Beaver Meadow, slope No. 5 -	4250.50	88.310	6.274	7.115	286.00	266.00	202.00	36 00	0.263	2.416	1.423	6.250	691.40	10.662	1.831
Forest Improvement - -	3810.00	91.689	6.524	7.001	253.95	274.79	167.17	45 69	0.257	3.320	1.423	6.250	805.50	12 886	2.133
Peach Mountain - - -	7371.87	94.174	6.694	6.940	305.38	252.43	201.97	57.74	0 264	3.537	1.436	6.432	877.38	14.037	2.347
Lehigh - - - -	3838.25	101.521	6.947	8 197	219.60	287.31	163.60	57.00	0.375	3.263	1.446	6 583	727.62	11.631	1.927
Lackawanna - - -	4112.51	97.394	6.450	7.264	271.27	268.62	202.45	39.30	0.284	2.666	1.425	6.280	744.99	11.919	1.971
Lyken's Valley - - -	2471.00	97.352	6.919	7.420	263.46	265 18	165.96	34.25	0 293	2.627	1.420	6.207	805.81	12.891	2.134
Beaver Meadow, (navy yard) -	1897.31	75 179	4.626	8.005	238.61	277.38	182.86	48 38	0.252	5 083	1.425	6.283	589.11	9.425	1 560
Natural coke of Virginia - -	4209.00	114.740	8.154	8 337	264.03	268.30	186.38	40.12	0.275	1.745	1.434	6.417	765.27	12.562	2.080
Coke of Midlothian (Va.) coal -	1037.00	135.676	9.643	8.413	192.40	301.39	145.00	70.11	0.373	2.000	1.492	7.272	1031.60	16.505	2.733
Coke of Neff's Cumberland (Md.) coal	994.25	119.547	8.427	7.959	219 57	276.93	144.57	47.91	0.361	1.166	1.426	6.285	931.95	14.911	2.469
Mixture, one-fifth Midlothian and four-fifths Beaver Meadow -	2050.00	94.679	5.826	8.143	263.71	270.77	204.34	41.65	0.236	3.208	1.436	6.441	738.59	11.818	1.665
Mixture, one-fifth Cumberland and four-fifths Beaver Meadow -	2074.00	127.640	7.984	7.856	278.99	288.86	221.93	59.27	0.262	2.250	1.449	6.635	842.00	13.470	2.122

SYNOPTICAL TABLE LV—Continued.

Designation of coals.	Evaporation. Steam, in pounds, corrected for temperature of water in cistern, to: One of fuel, from initial temperature.	One of fuel, from 212°.	One cubic foot of fuel, from 212°.	One of combustible matter, from 212°.	Effect of open air plate: (+*gain*, —*loss*.) On economy of fuel, per cent.	On rapidity of evaporation, per cent.	Residue from furnace. Total of clinker and ashes, from 100 of fuel.	Clinker alone, from 100 of fuel.	Ratio of clinker to total waste.	Pounds of unburnt coke, after each trial.	Lead reduced from litharge. By one of fuel.	By one of combustible matter.
Beaver Meadow, slope No. 3 -	8.200	9.207	505.54	10.462	+2.74	+ 5.41	11.958	1.012	0.0910	112 370	29.168	32 415
Beaver Meadow, slope No. 5 -	8.762	9.879	556.11	10.592	—2.35	—32.14	6.745	0.596	0.0924	61.250	31.858	33.289
Forest Improvement - -	8.920	10.058	540.78	10.807	—0.13	—19.14	6.970	0.811	0.1248	40.188	32.022	33.392
Peach Mountain - - -	8.960	10.112	545.69	10.871	—1.24	—18.82	6.969	3 030	0.4347	26.646	30.953	33.492
Lehigh - - - -	7.726	8.932	494.00	9.626	—5.37	—20.25	7.223	1.079	0.1496	36.125	27.377	28.924
Lackawanna - - -	8.564	9.789	477.67	10.764	+0.79	-	8.927	1.241	0.1411	57.190	31.630	33.532
Lyken's Valley - - -	8.428	9.463	459.65	10.789	+8.55	+ 4.48	12.245	4.403	0.3751	18.000	31.155	32.603
Beaver Meadow, (navy yard) -	7.862	9.079	500.04	9.881	-	-	8.104	1.400	0.1731	107.080		
Natural coke of Virginia - -	7.475	8.473	395 29	10.389	+3.95	+ 1.215	18.461	5.314	0.2923	43.687	31.344	32.491
Coke of Midlothian (Va.) coal -	7.403	8.632	282.56	10.343	-	-	16.545	10.514	0.6354	9.500		
Coke of Neff's Cumberland (Md.) coal	7.853	8.997	284.02	10.381	-	-	13.336	3.550	0.2662	16.000		
Mixture, one-fifth Midlothian and four-fifths Beaver Meadow -	7.690	8.861	481.08	9.725	-	-	8.885	4.913	0.5532	60.875		
Mixture, one-fifth Cumberland and four-fifths Beaver Meadow -	7.966	9.180	498.50	9.997	-	-	8.176	3.087	0.3736			

Remarks on the foregoing table.

It appears that the anthracites proper weigh, on an average, 53.35 pounds per cubic foot; and, consequently, require 42 cubic feet of space to stow 1 ton. The natural coke of Virginia requires 48, and the artificial coke from Midlothian and from Cumberland coal an average of 69.7 cubic feet to accommodate the same weight. Under the head of "evaporation," it will be observed that the average effect of 1 pound of anthracite was to convert into steam, from water at 212°, 9.565 pounds.

The last two columns of the above table are devoted to an exhibition of the reductive power of the several coals, when tested by the method of the celebrated French chemist, M. Berthier. The present occasion may afford a suitable opportunity to state the precautions which were observed in conducting the experiments on this subject. The coals in their raw state were reduced to an impalpable powder. A separate experiment was made, to ascertain the quantity of moisture which they contained; and then on another portion, also in the raw state, the trial with litharge was made. The powder, generally not exceeding 20 grains, was very intimately mixed with about forty times its weight of good English litharge, and placed in the bottom of a clean Hessian crucible, of such capacity that, when the mixture was covered with 500 or 600 grains of pure litharge, it was not more than half filled. The crucible thus charged was placed on a brick support in the centre of the small furnace L, (fig. 2, plate II,) in which the fire had been previously lighted, and suitably covered, to prevent the danger from particles of combustible matter falling into it. The heat was gradually brought up to redness, at which it was maintained for some ten or fifteen minutes, or until the ebullition of the mass had nearly abated. The heat was then pretty rapidly augmented until all the litharge resting above the charge was in complete fusion; at which it remained a few minutes, to allow so much action on the silica of the crucible as to facilitate the subsequent detachment of the button of lead from the unreduced oxide, as well as from the crucible itself, and to obviate error from the intermixture and adhesion of litharge. Wherever there was reason to believe that an imperfect result had been obtained, a repetition of the experiment was resorted to. It is obvious that all comparisons of this method of determining heating powers with the practical one by evaporation, ought to be made after deducting the proportion of waste or incombustible matter from the total weight of coal submitted to trial in each case. If we compare the numbers in the column which marks the production of *steam to 1 of combustible matter from* 212° with those found in the *last column* of the table, we have the following order, which shows how far the method of Berthier coincides in its indications with the operations of the steam boiler:

	Steam to 1 of combustible.	Lead reduced to 1 of combustible.
1. Peach Mountain - - -	10.871	33.492
2. Forest Improvement - -	10.807	33.392
3. Lyken's valley - - -	10.788	32.603
4. Lackawanna - - -	10.764	33.532
5. Beaver Meadow No. 5 - -	10 592	33 289
6. Beaver Meadow No. 3 - -	10 462	32.415
7. Natural coke - - -	10.389	32.491
8. Lehigh anthracite - - -	9.626	28.924

Subsequent comparisons will add much information to that above conveyed.

CLASS II.

FREE-BURNING BITUMINOUS COALS OF MARYLAND AND PENNSYLVANIA.

SAMPLES.

Maryland coals.

No. 1. New York and Maryland Mining Company.
2. Neff's.
3. Easby's "coal in store."
4. Atkinson and Templeman's.
5. Easby and Smith's.
6. Cumberland, (navy yard.)

Pennsylvania coals.

7. Dauphin and Susquehanna.
8. Blossburg.
9. Lycoming creek.
10. Quin's run.
11. Karthaus.
12. Cambria county.

General characters.

In specific gravity, coals of the free-burning class fall a little below the anthracites, ranging from 1.28 to 1.44. Their mean weight per cubic foot is, however, only two-thirds of a pound less than that of the first class. As they contain but a small portion of matter to be vaporized, they soon come to the temperature of full ignition. The considerable increase of volume which they take in coking, favors the subsequent rapid and effective combustion of their fixed carbon. In some cases, especially when brought very gradually to ignition, their masses of coke scarcely cohere, and the original forms of their lumps are in a measure preserved.

No. 1.

Bituminous coal from the New York and Maryland Mining Company.

This sample was accompanied by a letter from Mr. Henry Morris, of which the following is a copy:

"WASHINGTON, *December* 30, 1842.

"SIR: I am requested by William Young, Esq., president of the New York and Maryland Mining Company, to forward to the navy yard at Washington four casks of coal, marked Nos. 1, 2, 3, and 4. I herewith send them. Nos. 1, 2, and 4, are intended to be tested by Professor Johnson in evaporating water, so as to determine their value for the steam vessels; No. 3 to be tried in the anchor and cable shops, to determine its value compared with other coals for smith's use generally.

"Very respectfully, your obedient servant,

"HENRY MORRIS.

"Captain KENNON,
"*Commander of the yard, Washington.*"

This coal was of the kind commonly denominated "Cumberland coal," derived from the extensive coal trough lying a few miles to the northwest of the town of Cumberland, Allegany county, Maryland.

Its exterior characters are—a structure varying from slaty to columnar; its color a dull or shining deep black, according as the former or the latter portions are regarded.

The surfaces of fresh fractures are sometimes striated. An efflorescent sulphate of iron, in very thin lines, is occasionally discernible. The main cleat, or parting, is at right angles to the surface of deposition, and extends frequently through the slaty as well as the columnar portions.

The columnar portions are much more friable, less dense, and more free from earthy matter, than the parts which exhibit a slaty structure, as will be more particularly demonstrated in regard to another sample of coal from the same district.

The specific gravity of two specimens from this sample was found to be 1.438 and 1.424; the mean of which (1.431) gives the calculated weight per cubic foot in the mine 89.435 pounds.

Twenty experiments in measuring and weighing charges of two cubic feet each, gave a mean weight of 53.7 pounds per cubic foot. Hence the actual weight per cubic foot in the merchantable condition is 0.6004 as great as the calculated weight in the mine.

On consulting the columns under the head "*weight of charges of coal,*" it will be seen that the variation in the weight of two cubic feet was, according to size of lumps, from 95.75 to 118.25 pounds; the mean of which is 107, or 53.5 pounds per cubic foot.

It will commonly be observed that the greater weights are given when a considerable portion of fine coal is mixed with the lumps. Such will in general be found as an effect of giving the "average" sizes to coal, instead of its being measured and weighed entirely in lumps. This will be more fully evinced hereafter.

The space required for the stowage of one gross ton of this coal will be 41.71 cubic feet.

The moisture found in the first of the above specimens was but 0.803, and in the second 2.77 per cent. In an experiment on 28 pounds dried in the steam apparatus, the loss was 1.785 per cent.; which may therefore be safely assumed as the weight of water in 100 pounds of this coal, after some months' repose under cover, and in a moderately dry situation.

In addition to the moisture, the volatile matter at redness was found to be in the first specimen 12.902, and in the second 11.65; or the total volatile matter of the former was 13.705, and of the latter 14.44.

By complete incineration, the first left of a light gray ashes 18.93, and the second 18.318. Hence the composition of the two specimens may be stated as follows:

	Specimen *a*.	Specimen *b*.
Moisture - - - - -	0.803	2.770
Volatile combustible matter - -	12.902	11.650
Earthy matter - - - -	18.930	18.318
Fixed carbon - - - -	67.365	67.262
	100.	100.

Ratio of volatile to fixed combustible = 1 to 5.222, and 1 to 5.773.

In burning 2127.75 pounds of this coal, there were obtained in all 280.677 pounds of waste, of which 155.75 were ashes intermixed with minute fragments of coke, and 124.927 were clinker; or the latter was 44.5 per cent. of the *total waste;* and the mean of the latter, compared with the weight of coal consumed, is 13.19 per cent. This result differs widely from that obtained from the two specimens above described; but, on reference to the two following tables, in which the experiments on combustion are detailed, it will be perceived that they present even greater discrepancies between themselves. From the first trial, it appears that the per centage of waste was 17.903, and from the second only 7.514. During the second trial, was burned the residue, after portions had been taken to the anchor and chain shops from the hogshead which had been designated by the letter above cited for trials on working iron.

From this it appears that the coal of this cask was much more free from earthy matter than that of the others. The specimens above analyzed were taken from one of the other casks.

On reincinerating a portion of the ashes obtained from the two trials, they were found to have contained 13.27 of their weight of carbon. The cinder gave no reduction of weight by a like treatment. Hence it appears that the *waste* was really made up of—

Ashes - -	135.095 pounds	= 6.349 per cent. of the coal.		
Clinker - -	124 927	"	5 870	" "
Carbon - -	20.675	"	0.971	" "

The clinker is in large spongy masses of a black or a deep brown color. Portions of unreduced shaly skeletons of the fragments of slate adhere to the exterior. This large amount of clinker would constitute a serious objection to the use of the coal under steam boilers. The purest portions burned on the second day's trial gave 3.4 pounds of clinker to 100 of coal.

The ashes weigh 37.79 pounds per cubic foot, and the clinker 41.75 pounds.

After two days' burning, the flues yielded of soot and dust 8½ pounds; of which 52.73 per cent. were volatile and combustible, and the rest a light red gritty ash—rather lighter in color than that from the reincinerated ashes of the grate.

The trial of this coal in the chain shop proved it to work remarkably well, producing a strong heat without a great deal of flame. Sixty pounds of it were found sufficient for the putting in and finishing of 20 links of a 1⅜-inch chain—a higher result than was obtained from any other coal tested on the same chain. The cinder is small in quantity, and very little or no smoke was given off. The sample, having been selected expressly for this object, was doubtless more favorable in its effects than would have been the other portions of the sample, which, as above stated, yielded upwards of 17 per cent. of earthy residuum, instead of 7.5 per cent., as given by this cask. In the anchor shop, it was found to work very clear from cinder, to give a very light coke, but not to be capable of forming a hollow fire at all.

The facility with which this coal ignites, and comes to a uniform rate of combustion, is indicated by the time occupied from the commencement of charging to the arrival of the period of steady action in the boiler. This on the first trial was 1.25 hour, and the second 1.416 hour. In the quantity of unburnt coke withdrawn after the fire had become extinct, (which was in the first case 15.25, and in the second but 5 pounds,) we have an index of the degrees of facility with which the combustion is continued.

In burning this coal, it was remarked that it ignites readily; burns with a deep red flame of moderate size; agglutinating while coking into tolerably solid masses, preventing the falling of fragments through the interstices of the grate. The coke is consumed more slowly than that of the highly bituminous coals. During the first trial, it was twice found necessary to remove a stratum of clinker from the grate, as the combustion became impeded. On the second trial, when the purer coal was used, this expedient was unnecessary—the fire continuing sufficiently active during the day.

Tried by litharge, specimen *b* (of which the specific gravity and the earthy impurity were less than in the case of *a*) gave but 24.775 times the weight of the coal in metallic lead. But, as there were 18.318 per cent. of earthy matter in this coal, the truly combustible portion was only 81.682 parts in 100; and dividing the above weight of lead by this, we obtain 30.331 as the number representing the reductive power of the combustible matter.

TABLE LVI.—NEW YORK AND MARYLAND

First trial—upper damper 8 inches open ; air plates closed ;

Date.	Hour.	Temperatures of the							Height of barometer.		Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m. A. M.													
Sept. 18	4.55	72.5	72	128	–	76	168	76	30 10	0	7.04	0.09	–	–
	6.45	75	73	128	235	77	212	[illegible]	30.11	0	6.26	0.22	–	–
	7.15	76	73	140	232	77	229	75	30.12	0	5.07	0.23	–	97.25
	7.30	76	73	146	210	77	231	75	30.12	0	5.30	0.27	162	102.50
	[illegible]	76	73	152	274	77	232	75	30.12	0	5.05	0.35	398	–
	8.30	77	74	160	275	76	230	76	30.12	0	5.06	0.28	585	104.50
	9.00	78	75	174	282	77	232	76	30.13	0	5.02	0.28	998	–
	9.30	81	76	185	276	[illegible]	230	[illegible]	30.13	0	5.05	0.26	1722	95.75
	10 15	84	78	204	[illegible]	75	231	80	30.14	0	5.17	0.23	2378	–
	10.45	86	78	215	275	75	232	[illegible]	30.14	0	5.10	0.25	2712	–
	11.00	87	79	218	272	[illegible]	231	82	30 14	0	5.10	0.25	2967	117.00
	11.30	90	79	226	264	75	231	84	30.13	0	5.12	0.24	3361	–
	P. M. 0.00	89	79	232	[illegible]	75	232	85	30.13	0	5.08	0.25	3615	106.00
	0.30	92	80	239	272	[illegible]	231	86	30.12	0	5.20	0.24	[illegible]	–
	1.00	92	80	242	280	76	230	86	30.11	0	5 22	0.24	4630	115.75
	1.30	94	80	248	270	76	231	88	30.11	0	5.22	[illegible]	5042	–
	2.05	95	81	254	288	77	232	88	30.12	0	5.17	0.22	5368	–
	2.30	95	81	258	284	77	232	89	30.11	0	5.20	0.23	5690	113.00
	3.00	96	81	255	275	77	232	89	30.11	0	5.19	0.22	6143	–
	3.30	94	80	262	292	76	[illegible]	89	30.11	0	5.16	0.22	6482	–
	4.00	97	81	272	270	76	231	89	30.11	0	5.18	0.22	6827	111.75
	4.30	95	81	273	292	76	231	90	30.11	0	5.12	0.22	7162	–
	5.00	94	[illegible]	280	282	76	230	89	30.11	0	5.10	0.22	7540	118.25
	5.30	93	[illegible]	280	284	76	230	89	30.11	0	5.12	0.22	7864	–
	5.53	90	80	300	268	76	228	88	30.11	0	5.31	0.21	8655	–
Sept. 19	A. M. 5 35	76	73	207	204	78	218	79	30 19	0	6.24	0 15	8655	–
	5.50	76	73	205	–	79	216	78	30.19	0	6.32	0.15	8806	–

Period of steady action, from 8*h*. 30*m*. a. m. to 4*h*. 55*m*. p. m.=8*h*. 25*m*.; coal supplied to grate, 777.5 pounds; water to boiler, 6,892 pounds; water to one of coal for that time, 8,864.

MINING COMPANY'S BITUMINOUS COAL.

steam escaping from both valves; small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Morning very foggy; fire kindled in small furnace.
-	71.75	55.5	-	-	Commenced firing; safety valves double weighed at 5*h*. 15*m*. a. m.
-	72.2	53	+23	-	Made observations on rise of water in boiler from heat.
7.15	71.8	64	3	-	Wood consumed, 265 pounds: second weight removed from front valve; steam blows off.
7.37	71.8	70	18	1.690	Ash pit cleared out, and contents thrown on grate.
-	71.8	76	42	1.250	
8.30	72.8	83	45	0.991	
-	73.9	96	50	2.188	The first, second, third, and fourth charges of coal consist chiefly of lumps.
9.30	74.2	104	46	3.836	Filled tank at 10*h*. a. m.; the fifth charge very dirty, with much fine coal.
-	76.1	120	34	2.317	Wind SW., light; clear.
-	75.5	129	43	1.769	Placed 28 pounds of this coal in drying apparatus.
10.56	76.6	131	41	2.702	
-	75.8	136	33	2.088	Commenced drawing gases at 11*h*. 50*m*. from the new orifice; drew in 25 minutes 100 cubic inches, which gave water
11.50	76.0	143	54	1.346	1.59 grain, carbonic acid 5.89 grains, oxygen 9.444 cubic inches; temperature 87°.
-	76.6	147	41	3.126	The seventh, eighth, and ninth charges of coal nearly all fine.
1.05	76.6	150	50	2.252	Removed clinker from grate.
-	76.1	154	45	2.183	Commenced drawing gases at 1*h*. 40*m*. p. m from new ori-
-	77.3	159	56	1.478	fice; drew in 25.5 minutes 100 cubic inches, which gave
2.14	77.3	163	52	2.047	water 3.06 grains, carbonic acid 5.08 grains, oxygen
-	77.1	162	43	2.400	12.777 cubic inches; temperature 89°.
-	76.1	168	60	1.796	Filled tank at 3*h*. 25*m*. p. m.
3.45	76.8	175	39	1.828	Clinker removed from grate.
-	77.3	178	61	1.775	
4.55	77.5	186	52	2.003	The tenth charge some lumps, but chiefly fine.
-	77.8	187	51	1.717	Contents of ash pit thrown on grate at 5*h*. 40*m*.
-	77.2	210	40	-	Water in boiler left 1.2 inch above normal level.
-	71.8	131	—14	-	Water 0.8 inch below normal level; fire on grate.
-	71.8	129	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	79.75
Ashes	108.00
Ashes behind bridge	4.00
Total clinker and ashes	191.75
Deduct wood ashes	0.8135
Total waste from coal	190.9365
Coke	14.75

TABLE LVII.—NEW YORK AND MARYLAND

Second trial—upper damper 8 inches open; air plates open;

Period of steady action, from 9*h*. 25*m*. a. m. to 6*h*. 17*m*. p. m.—8*h*. 52*m*.; coal supplied to grate, 748 lbs.; water to boiler, 6,923.7 lbs.; water to 1 of coal for that period, 9 256.

MINING COMPANY'S BITUMINOUS COAL.

steam escaping from both valves, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	71.8	129	-	-	Clear; wind SW., light; water 0.6 inch below normal level; commenced firing; fire made in small furnace.
7.05	71.7	102	-	-	Wood consumed, 84½ lbs.; commenced charging with coal;
7.35	73.2	102	-	0.534	second weight taken from valves, and steam blows off at 7*h.* 25*m* a. m.
-	73.6	97	+41	0.901	Damper set at 8 inches, and air plates opened.
-	75.8	98	61	1.351	
-	74.9	102	86	2.114	
9.25	77.2	110	78	2.309	
-	77.2	125	76	1.875	Wind NE., light; clear; filled tank at 10*h.* 10*m.* a. m.
10.30	76.9	133	70	1.087	
-	76.6	144	72	2.307	Commenced drawing gases from new orifice at 11*h.* 5*m.*;
-	76.6	156	78	2.615	drew in 29.5 minutes 100 cubic inches, which gave water 1.88 grain, carbonic acid 6.5 grains, oxygen 10.209 cubic inches; temperature 88°.
11.50	76.6	170	46	2.460	Clouds flying from NE.; dew point, by observation, 75°;
-	76.6	176	77	2.215	by calculation, at same time and place, 75°.8.
1.00	76.4	187	80	2.278	
-	76.4	193	90	2.013	Removed a small additional weight from front valve.
-	76.25	189.5	87	2.162	
2.08	71.5	202	85	2.077	Filled tank.
-	71.5	206	71	2.219	
3.25	77.1	208	61	1.791	Owing to the very friable nature of the coal consumed to-day, it is nearly all fine.
-	75.9	209	83	2.241	Wind NE., brisk; clear.
-	76.1	212	73	2.022	No clinker removed from grate to-day.
-	78.0	216	87	1.828	
5.05	77.2	223	79	1.838	The coal of the two hogsheads consumed to-day appears
-	77.4	227	78	1.817	much more friable and less crystaloid in the large masses,
6.17	78.3	232	88	2.146	but of a more columnar structure internally, than that of the two consumed yesterday. It shows but little smoke at chimney top.
-	77.2	249	64	-	Air plates closed, and contents of ash pit thrown on grate, at 6*h.* 50*m.*; damper reduced to 3 inches.
-	71.0	148	— 9	-	Water in boiler left last night at 0.8 inch *above* normal level; this morning it is 2.4 inches *below* normal level.
-	71.0	144	— 6	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	36.25
Ashes	39.75
Ashes behind bridge	4.00
	80.00
Deduct wood ashes	0.26
Total waste from coal	79.74
Coke	5.00
Soot, (2 burnings)	8.5

TABLE LVIII.—DEDUCTIONS·

Experiments on the New York and

	Nature of the data furnished by the respective tables.	1st Trial. (*Table LVI.*)	2d Trial. (*Table LVII.*)
		September 18.	*September* 19.
1	Total duration of the experiment, in hours - - -	24.917	24.583
2	Duration of steady action, in hours - - - - -	8.417	8.867
3	Area of grate, in square feet - - - - -	14.07	14.07
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	18.75	18.75
6	Number of charges of coal supplied to grate - - -	10.0	10.0
7	Total weight of coal supplied to grate, in pounds - -	1081.75	1066.25
8	Pounds of coal actually consumed - - - - -	1066.5	1061.25
9	Pounds of coal withdrawn and separated after trial - -	15.25	5.0
10	Mean weight, in pounds, of one cubic foot of coal - -	54.0875	53.3125
11	Pounds of coal supplied per hour, during steady action -	92.376	84.367
12	Pounds of coal per square foot of grate surface, per hour -	6.565	5.996
13	Total waste, ashes and clinker, from 100 pounds of coal -	17.903	7.514
14	Pounds of clinker alone, from 100 pounds of coal - -	7.4473	3.4046
15	Ratio of clinker to the total waste, per cent. - - -	41.598	45.31
16	Total pounds of water supplied to the boiler - - -	8806.0	9783.0
17	Mean temperature of water, in degrees Fahrenheit - -	76°.0	78°.5
18	Pounds of water supplied at the end of experiment, to restore level - - - - - - - - -	151.0	862.0
19	Deduction for temperature of water supplied at the end of experiment - - - - - - - -	20.0	106.0
20	Pounds of water evaporated per hour, during steady action -	818.848	780.927
21	Cubic feet of water per hour, during steady action - -	13.1	12.49
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - -	2.169	2.068
23	Pounds of water per square foot, by a mean of several observations - - - - - - - -	2.183	2.058
24	Water evaporated by 1 of coal, from initial temperature (a) final result - - - - - - -	8.238	9.118
25	Water evaporated by 1 of coal, from initial temperature (b) during steady action - - - - - -	8.861	9.256
26	Pounds of fuel evaporating one cubic foot of water - -	7.5857	6.8546
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - - - - -	89°.25	95°.55
28	Mean temperature of wet bulb thermom., during steady pressure	79°.9	79°.95
29	Mean temperature of air, on arriving at the grate - -	231°.6	268°.81
30	Mean temperature of gases, when arriving at the chimney -	278°.6	309°.9
31	Mean temperature of steam in the boiler - - -	231°.15	233°.43
32	Mean temperature of attached thermometer - - -	84°.5	87°.1
33	Mean height of barometer, in inches - - -	30.1205	30.242
34	Mean number of volumes of air in manometer - -	5.132	5.1543
35	Mean height of mercury in manometer, in atmospheres -	0.544	0.5419
36	Mean height of water in syphon draught gauge, in inches -	0.2365	0.2266
37	Mean temperature of dew point, by calculation - -	75°.96	76°.21
38	Mean gain of temperature by the air, before reaching grate -	142°.35	173°.26
39	Mean difference between steam and escaping gases - -	47°.06	76°.78
40	Water to 1 of coal, corrected for temperature of water in cistern - - - - - - - - -	8.2114	9.086
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - - -	9.2956	10.2592
42	Pounds of water, from 212°, to 1 cubic foot of coal - -	502.77	546.94
43	Water, from 212°, to 1 pound of combustible matter of the fuel - - - - - - - - -	11.323	11.0927
44	Mean pressure, in atmospheres, above a vacuum - -	1.4464	1.4447
45	Mean pressure, in pounds per square inch, above atmosphere	6.592	6.5675
46	Condition of the air plates at the furnace bridge - -	Closed.	Open.
47	Inches opening of damper, (U. upper) - - -	U. 8	U. 8.

FROM TABLES LVI, LVII.

Maryland Mining Company's coal.

Averages.	Remarks.
10.125	
53.7002	
88.371	
6.2805	
12.7085	The great difference in the amount of earthy matter, on the two trials, has already been referred to.
5.4259	
43.454	
799.887	
12.795	
2.1185	
8.678	The difference in the results of the two trials is explained by the difference in the amount of waste in the two cases, respectively.
9.06	
7.2201	
250°.2	
294°.25	
0.2315	
157°.805	
61°.921	
8.6487	
9.7774	
524.855	
11.2078	The difference of evaporative effect of the coal on the two trials in line 41, is made to assume an opposite character in this line, by the deduction in each case of the amount of *waste*.
1.445	
6.5797	

No. 2.

Bituminous coal from Mr. John Neff's mines, in the neighborhood of Frostburg, above Cumberland.

This sample, sufficient for four trials on evaporation, was taken from a boat load of the same coal delivered by the proprietor, under a contract with the department, at the navy yard, Washington.

In exterior characters, this coal is generally similar to all those from the same district which have been examined. It was taken indiscriminately from the heap, and the lumps were not separated from the fine parts.

The larger masses exhibit the same crystaloid appearances already noticed, with the occasional occurrence of a radio-striated surface.

The main partings are perpendicular to the surfaces of deposition. The partings of "clod," or carbonaceous matter, retaining something of the organic structure, are pretty abundant, and fractures are easily made, which display the forms of vegetable impressions.

The specific gravity of two specimens was found to be, respectively, 1.3429 and 1.3221, whence the mean weight per cubic foot in the mine is 83.28 pounds.

Forty trials by measuring and weighing in the charge box showed the mean weight per cubic foot, in the marketable state of average fineness, 54.287 pounds; or the weight calculated from the specific gravity is to that obtained by experiment as 1 to 0.6519.

The space required for the stowage of 1 gross ton is 42.126 cubic feet.

The extremes of weight per cubic foot in the whole series are $\frac{98.75}{2} = 49.375$, and $\frac{117}{2} = 58.5$, as will be seen on consulting the column of charges in the tables of experiments. The mean of these two (53.927) is sufficiently near the general mean above given, to warrant a full reliance upon its realization in practice.

The trial for moisture in the steam-drying apparatus resulted in the expulsion of 11 ounces from 28 pounds of this coal, or 2.455 per cent.

The volatile matter of the first specimen, of which the specific gravity is given above, was found to be 14.05 per cent., and that of the second 16.21 per cent.

The incineration of the same specimens left of the first 11.414, and of the second 8.538 per cent. The ashes are moderately dense, and of a nearly flesh-red color.

There were burned in four trials 4318.38 pounds of this coal, and withdrawn from the furnace 196.25 pounds of clinker, equal to 4.5446 per cent.; and 277.008 pounds of ashes, equal to 6.4106 per cent. Hence the clinker is 41.468 per cent. of the total waste.

The clinker is in dark brown, spongy, rather friable masses, including considerable portions of shaly and other unvitrified materials, which are of a somewhat lighter color than the portions which have undergone complete fusion. It does not adhere to the grate, or spread into impermeable sheets, like the cinders of some other coals which have been examined. It contains 0.896 per cent. of carbon. Its weight in the charge box was found to be 32.12 pounds per cubic foot.

The ashes are of a reddish gray color, and weigh 37.2 pounds per cubic foot. They contain 10.06 per cent. of carbon.

The soot taken from the flues after four days' burning weighed 14.625 pounds, and was of such density that 12.64 pounds made 1 cubic foot. Its incombustible portion is 33.16 per cent.

The facility with which this coal ignites is indicated by the times required in the four trials to bring the boiler to a uniform rate of evaporation. These were—

	1.416	hour for the first; coal in lumps.
	2.500	hours for the second; coal all fine.
	1.800	hour for the third; coal mixed.
	1.000	hour for the fourth; coal in lumps.
Mean	1.679	

It is evident that the coarseness or fineness of the coal has been an important element in deciding the promptitude with which the combustion was brought to its average rate.

The mean weight of unburnt coke withdrawn at each trial was 6.155 pounds.

In the chain shop, 60 pounds of this coal were sufficient to make eight links of $1\frac{1}{8}$-inch chain. Its efficiency was, therefore, the same as that of Atkinson & Templeman's coal, to be hereafter described; and in the anchor shop it worked well, made a good hollow fire, but gave a large amount of cinder, which accords well with the considerable per centage of waste drawn from the steam boiler furnace.

A trial by the oxide of lead resulted in reducing of metallic lead 26.457 times the weight of raw coal employed. Deducting the ashes, 11.414 per cent., the lead to 1 of remaining material was 29.866; and deducting farther 2.455, the per cent. of moisture determined in the large way, the *lead* to 1 of real combustible is 30.717.

In the gas works, this coal would be found to produce a gas too small in quantity, and too low in illuminating power, to be employed with profit.

In the blast furnace, it will sustain the same character as the other samples from the same coal region, with perhaps the exception of demanding more expenditure of power in reducing its higher proportion of earthy impurities.

It forms a dense coke, very suitable for smelting iron. An experiment of considerable magnitude on coking this coal was made for another purpose, while the experiments on evaporation were in progress. The evaporative power and other properties of that coke have already been detailed.

From preceding data, the composition of this sample may be stated as follows:

Moisture, from drying 26 pounds - - -	2.455
Volatile matter other than moisture (two specimens)	12.675
Earthy matter, from 4318.38 pounds - -	10.343
Fixed carbon, by difference - - -	74.527
Ratio of volatile to fixed combustible - -	1:5.88

By reference to the column of "remarks" in the tables of experiments, it will be perceived that the combustion of this coal caused in the grate bars a constant tendency to redness, and a consequent liability to flexure and derangement.

TABLE LIX.—NEFF'S

First trial—upper damper 8 *inches open ;*

Date.	Hour.	TEMPERATURES OF THE: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
Oct. 14	A. M.													
	5.00	47	42	143	149	58	184	48	30.14	0.372	6.84	0.19	-	-
	7.00	47	42	132	271	59	228	47	30.18	0.572	4.86	0.30	-	106.75
	7.30	49.5	45	143	263	59	232	47.5	30 21	0.558	5.00	0,40	158	108.00
	8.20	53	49	166	313	59	233	49	30.22	0.565	4.92	0.43	837	-
	9.00	53	47	178	302	57	232	51	30.22	0.565	4.92	0.43	1577	107.75
	9.30	55	49	192	312	57	233	53	30.23	0.563	4.95	0.41	2253	102.75
	10.00	55	49	206	306	57	233	54	30 23	0.574	4 84	0.40	2727	-
	10.30	56	50	214	315	57	234	55	30.25	0.574	4.84	0.40	3169	117.00
	11.00	59	52	230	313	57	235	56	30 25	0 593	4.65	0 39	3784	-
	11.25	59	52	236	326	57	237	56	30.25	0 605	4.53	0.38	4217	105.75
	P. M.													
	0.00	61	54	250	323	56	236	56	30.25	0.586	4.72	0.37	4880	111.00
	0.30	62	54	260	318	56	236	57	30 24	0.581	4.74	0.39	5412	-
	1.00	62	55	266	320	56	235	57	30.24	0.583	4.75	0.38	5708	110.75
	1.38	65	55.5	273	318	56	234	57	30.24	0.575	4.83	0.40	6397	113.00
	2.00	65	56	277	325	56	234	58	30.22	0.576	4.81	0.36	6652	-
	2.30	65	55	280	316	56	233	58	30.23	0.565	4.92	0.35	7377	110 00
	3.10	66	55.5	290	330	57	232	58	30.23	0.562	4.96	0 33	7892	-
	3.50	64	54	282	298	57	231	59	30.23	0.552	5.05	0.30	8312	-
	4.10	62	51	290	262	57	229	58	30.23	0 512	5.46	0.30	8992	-
	5.55	57.5	50	280	220	56	226	57	30.25	0.523	5.34	0.28	9158	-
	8.10	52	47	278	206	56	228	55	30.26	0.527	5.30	0.24	9158	-
	A. M.													
Oct. 15	7.25	45	42	193	183	54	208	47	30.23	0.374	6.82	0.21	9162	-
	7.45	48	44	190	181	54	206.5	47	30 23	0.372	6.84	0.20	9196	-

Period of steady action this day extends from 8*h*. 25*m*. a. m. to 2*h*. 30*m*. p. m. = 6*h*. 5*m*.
Coal supplied to grate, 770.25 lbs.; water to boiler, 6,447.5 lbs. during that time.

(CUMBERLAND) COAL.

air plates closed; and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
					Morning clear; wind NW.; water brought to 0.36 inch below normal level.
h. m.					
-	31.9	96	—35	-	Commenced firing; and fire kindled in small furnace at 5*h*. 35*m*. a. m.
7.00	31.9	85	+43	-	Wood consumed, 221 lbs.; commenced charging with coal; steam blows off at 7*h*. 5*m*.
7.41	37.5	93.5	31	0.837	
-	43.8	113	80	2.158	Filled tank at 8*h*. 34*m*. a. m.
8 25	38.1	125	70	2.940	
9.29	41.1	137	79	3.581	Small additional weights on both valves.
-	41.1	151	73	2.511	
10.30	42.6	158	81	2.342	28 lbs. of this coal was placed in the drying apparatus.
-	44.3	171	78	3.258	Front valve double weighed at 10*h*.40*m*., to prevent priming.
11.08	44.3	177	89	2.752	Filled tank at 11*h*. 40*m*. a. m.
11.58	47.1	189	87	3.010	Grate bars cherry red.
-	46.2	198	82	2.818	Steam allowed to escape slowly from front valve; to prevent priming, the level of water in boiler, hereafter during this experiment, kept 1 inch below normal level;
0.52	48.5	204	85	1.568	
1.44	47.0	208	84	2.882	
-	48.2	212	91	1 842	grate bars cooled down.
2.30	45.8	215	83	3.841	The coal of this day's experiment generally fine.
-	43.2	224	98	2.046	
-	44.3	218	67	1.669	Contents of ash pit thrown on grate.
-	38.3	228	32	-	Damper reduced to 3 inches at 4*h*. 0*m*. p. m; water brought to 0.3 inch above normal level; partly filled tank at 5*h*. 55*m*.; water in boiler brought to 0.35 inch above normal level.
-	40.8	222.5	— 6		
-	39.6	226	—22	-	Water 0.28 inch above normal level.
-	36.1	148	—25	-	Water 0.2 inch below normal level.
-	37.0	142	—25.5	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	56.50
Ashes - - - - - - - - - - -	66.25
Ashes behind bridge - - - - - - - - - -	5.906
Total clinker and ashes - - - - - - - -	128.656
Deduct wood ashes - - - - - - - - -	0.678
Total waste from coal - - - - - - - -	127.978
Coke - - - - - - - - - - - -	7.50

TABLE LX.—NEFF'S

Second trial—upper damper 8 inches open; air plates open;

			TEMPERATURES OF THE						Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
			Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
			47	180	154	64	172	52	30.00	0.366	6.89	0.16	-	-
			50	126	268	54	226	51	29.99	[illegible]	4.52	0.30	-	110.00
			51	132	263	54	232	52	29.97	0.574	4.64	0.46	-	-
			51	138	291	54	232	[illegible]	29.97	0.558	5.00	0.40	160	110.75
			52	140	319	54	233	56	29.96	0.553	5.04	0.37	337	-
			55	146	326	54	232	57	29.96	0.551	[illegible]	0.38	675	106.25
			57	166	316	55	232	59	[illegible]	0.541	5.16	0.34	1131	-
			55	170	336	55	232	60	[illegible]	0.555	5.		1476	-
			56	179	329	56	233	[illegible]	29.96	0.555	5.		2024	104.00
			58	187	309	56	232	61	29.95	0.548	5.		2304	-
			58	192	296	57	232	61.5	29.93	0.544	5.		2612	103.75
			55	195	324	57	232	61	29.92	0.544	5.		2949	-
			54	192	343	57	233	60	29.93	0.549	5.		3369	109.00
			54	196	330	57	234	60	29 93	0.571	4.		[illegible]	-
			51	200	345	57	334	58	29 93	0.575	4.		4314	109.75
	3 30	62	53	204	334	57	234	58	29.93	0.574	4.		[illegible]	-
	4.00	63	54	210	337	57	234	[illegible]	29.94	0.566	4.		5214	109.25
	4.30	63	54	217	337	57	234	58	29.93	0.563	4.		5704	-
	5.00	64	56	222	354	57	234	58	29.95	0.568	4		6202	[illegible]
	5.30	64	55	234	343	57	238	58	29.94	0.572	4		6696	-
	6.00	66	57	238	352	57	233	58	29.95	0.564	4		7292	106.50
	6.25	64	54	248	320	58	231	58	29.95	0.548	5		8162	-
	8.27	57	48	266	[illegible]	58	229.[illegible]	56	29.96	0.513	5		8505	-
	A. M.													
Oct. 17	4.15	49	44	210	194	56	224	49.5	29.95	0.477	5		8505	-
	4.50	48	42	206	194	56	222	49	29.95	0.459	5		8541	-

The period of steady action, from 10*h*. a. m., to 5*h*. 43*m*. p. m., embraces 7*h*. 43*m*.; the coal supplied to the grate in that time, was 751.75 lbs.; and the water to the boiler, 6,279.26 lbs.; giving of water to 1 of coal, 8.352.

(CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 68 feet.
h. m.					Morning clear; wind SW., light.
-	44.1	81	— 18	-	Water in boiler 0.47 inch below normal level; commenced firing.
8.05	45	72	+ 42	-	Tank partly filled at 7*h.* 10*m.* a. m.; wood consumed 255½ lbs.; commenced charging with coal.
-	46.3	77	31	-	Steam allowed to escape, and air plates opened.
8.35	45.2	82	59	0.726	To prevent priming, a temporary level, one inch below the true normal level, will be kept during this day's operations;
-	45.4	82	86	0.938	second weight removed from back valve at 9*h.* 30*m.* a. m.
10.00	49.4	85	94	1.791	The coal burned this morning is nearly all fine, producing rather slow combustion and action; tank partly filled at
-	51.2	102	83	2.070	10*h.* 25*m.* a. m.
-	45.8	105	104	2.193	Smoke 18″.5 in reaching chimney top; syphon 0.39.
11.11	47.3	113	96	1.935	At 11*h.* 11*m.* a. m., wind NW., light; overcast; placed second weight on back valve.
-	50.2	119	76	1.801	
0.30	50.2	124	64	1.314	
-	45.8	130	92	1.785	
2.00	46.2	130	110	1.483	
-	46.2	134	96	2.697	
2.52	40.6	140	111	2.309	
-	43.7	142	100	1.718	
3.44	45.1	147	103	3.019	The coal burned since sixth charge, being less fine, burns with more vigor; steam allowed to escape from back valve
-	45.1	154	103	2.596	by removing second weight.
4.34	49.0	158	120	2.638	Grate bars cherry red; fire in vigorous action; wind W., brisk; sky overcast.
-	46.7	170	110	2.614	Filled tank at 5*h.* 8*m.* p. m.; very little smoke from chimney to-day.
5.43	48.0	170	119	3.158	Air plates closed, and contents of ash pit thrown on grate.
-	44.3	184	89	-	Water in boiler left 1 inch above true normal level; at 8*h.* 4*m.* p. m., water 0.33 inch below normal level.
-	34.7	209	10.5	-	Water 0.4 inch above normal level.
-	33.1	161	— 30	-	Water 0.07 inch above normal level.
-	29.7	158	— 28	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	43.25
Ashes - - - - - - - - - - -	69.25
Ashes behind bridge - - - - - - - - -	5.906
Total waste - - - - - - - - - -	118.406
Deduct wood ashes - - - - - - - - -	0.784
Total waste from coal - - - - - - - -	117.622
Coke - - - - - - - - - - -	7.75

TABLE LXI.—NEFF'S

Third trial—upper damper 12 inches open;

The period of steady action this day is from 8*h*. a. m. to 2*h*. 25*m*. p. m.—6*h*. 25*m*.; coal to grate, 765.25 lbs: water to boiler, 6,179 lbs.; hence, water to 1 of coal, 8.074.

(CUMBERLAND) COAL.

air plates open; steam escaping from both valves.

		grate.	Difference of temperature between steam and escaping gases	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney [illegible] feet.
					Small furnace lighted at 4h. 50m.
-	[illegible]	144	— 23	-	Commenced firing; water 0.1 inch above normal level.
6.12	37.0	[illegible]	+ 31	-	Consumed 75.25 lbs. of wood; commenced charging with coal.
-	37.0	126	— 2		
7.06	37.0	123	+ 36	-	Steam allowed to escape at 6h. 40m.; to prevent priming, the water in boiler is kept 1 inch below true normal level;
-	39 2	123.5	100	0 852	second weight removed from back valve.
8.00	45.1	126	141	2.077	Air plates opened at 7h. 30m. a. m.; filled tank at 8h. a. m.
-	43.4	132	143	1.822	The 3d charge of coal is all lumps; weather clear; wind SW., brisk.
8.54	40.1	135	153	3.094	Grate bars cherry red; the 1st, 2d, and 4th charges of coal are about an average.
-	[illegible]	140	141	3.465	Fifth charge is nearly all fine coal.
9.41	[illegible]	147	144	2.336	Filled tank at 10h. 17m.; commenced drawing gases at
10.26	37.7	[illegible]	134	[illegible]	10h. 27m. a. m.; drew in 25 minutes 100 cubic inches, which gave water 0.95 grain, carbonic acid 5.99 grains, oxygen 10.145 cubic inches; temperature 57°.
-	[illegible]	155	120	3.549	Air plates closed at 11h. 29m.; wind W., overcast.
11.30	43.4	150	126	2.225	Commenced drawing gases at 11h. 49m. a. m.; drew in 29 minutes (air plates closed) 100 cubic inches, which gave
-	41.1	166	130	2.262	water 0.67 grain, carbonic acid 4.54 grains, oxygen 13.75 cubic inches, temperature, 58°.
0.[illegible]	41.7	164	135	2.267	Sun shining at 0h. 15m. p. m.; again overcast at 0h. 45m. p. m.
-	45.8	167	[illegible]	3 088	Air plates opened at 0h. 55m. p. m.
1.[illegible]	44.3	173	[illegible]	2.688	The 6th, 7th, 8th, and 9th charges are about one-half fine coal.
-	43 4	181	159	-	Filled tank.
2.25	45.7	176	153	1.700	
-	45.0	[illegible]	112	[illegible]	Air plates closed at 2h. 50m. p. m.; contents of ash pit thrown on grate; damper set at 4 inches.
-	45.7	168	86	-	Water in boiler brought to true normal level.
-	45.7	168	57	-	Water in boiler raised to 0.3 inch above normal level.
-	39.4	[illegible]	35	-	Water in boiler at 0.4 inch above normal level.
-	39.8	160	— 4	-	Water in boiler left at 0.23 inch above normal level.
-	36.6	146.5	— 24	-	Water 0.1 inch below normal level.
-	36.1	145	— 24	-	Water in boiler adjusted for temperature.

RESIDUA.

	Pounds.
Clinker	52.75
Ashes	54.00
Ashes behind bridge	5.906
Total	112 656
Deduct wood ashes	0.231
Total waste of coal	112 425
Coke	2.625

TABLE LXII.—NEFF'S

Fourth trial—upper damper 6 inches open; air plates closed; steam thrown

Date.	Hour.	Temperatures of the — Open air entering below ash-pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Oct. 18	6.25	49	45	186	187	54	213	50	30.00	0.390	6.66	0.20	-	-
	7.15	47.5	44	166	264	55	228.5	49.5	30.00	0.558	5.06	0.30	-	110.00
	7.30	49	44.5	166	274	55	230	49	30.00	0.550	5.04	0.40	-	-
	7.45	48	44	164	301	55	229	49	30.00	0.550	5.04	0.37	125	-
	8.15	50	46	168	340	55	230	49	30.02	0.570	4.88	0.41	238	-
	8.45	55	49	172	344	55	231	50	30.01	0.582	4.76	0.37	314	108.00
	9.15	55	50	180	312	55	230	53	30.01	0.575	4.82	0.34	973	108.00
	10.00	58	52	185	320	53	230	55	30.01	0.565	4.93	0.34	1626	-
	10.30	61	52	192	328	53	230	56	30.01	0.578	4.80	0.38	1796	107.00
	11.00	62	52	197	336	53	230	57	30.00	0.572	4.86	0.38	2296	-
	11.30	63	53	202	329	54	232	58	30.00	0.580	4.78	0.37	2890	115.00
	P. M.													
	0.00	64	54	206	336	54	234	59	29.99	0.570	4.88	0.37	3318	-
	0.30	66	55	210	320	54	234	60	29.97	0.574	4.84	0.36	3664	111.75
	1.00	66	55	214	326	54	236	60	29.96	0.570	4 88	0.38	3978	-
	1.30	66	55	223	324	54	236	61	29.94	0 571	4.87	0.35	4636	-
	2.00	67	55	226	338	54	236	62	29.93	0.576	4.82	0.36	5061	108.50
	2.40	69	56	228	330	54	235	62	29.93	0.564	4.94	0.34	5622	-
	3.00	68	56	232	339	57	235	62	29.93	0.574	4.84	0.37	5867	107.00
	3.30	70	56	232	355	57	235	63	29.93	0.560	4.98	0.38	6339	-
	4.00	69	56	239	332	57	234	63	29 91	0.563	4.95	0.36	6760	114.75
	4.30	70	57	216	334	57	235	63	29.90	0 563	4.95	0.39	7179	-
	5.00	69	58	250	333	57	235	63	29.90	0.563	4.95	0.37	7601	105.50
	5.30	65	54	250	338	57	233	63	29.91	0.553	5.04	0.34	8699	-
	9.45	63	53	242	220	57	231	59	29.88	0 532	5.25	0.24	8699	-
	10.05	62	52	239	216	57.5	226	59.5	29.87	0.488	5.67	0.24	9159	-
	A. M.													
Oct. 19	6.18	54.5	48	205	190	57	217	55	30.04	0.403	6.53	0.20	9162	-

The period of steady action this day is from 9*h.* 7*m.* a. m. to 4*h.* 49*m.* p. m. = 7*h.* 42*m.* Coal supplied to grate, 769.5 lbs.; water to boiler, 6,649 lbs.; sets of observations taken, 16; water to 1 of coal, 8.641; while the final result is 8.354.

(CUMBERLAND) COAL.

into chimney; small furnace in action, and coal in thin stratum on grate.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Morning clear; wind SW., light; double weights on safety valves.
-	38.4	137	—26	-	Commenced firing; water in boiler 0.1 inch below normal level.
7.15	37.8	118.5	+35.5	-	Wood consumed, 93 lbs.; commenced charging with coal;
-	36.9	117	44		steam escapes by removing second weight from valve at
-	37.0	116	72	1.324	7*h.* 26*m.*; damper set at 6 inches.
-	39.7	118	110	0.599	To prevent priming, the water in boiler to be kept 1 inch below true normal level.
8.27	41.1	117	113	0.403	Steam allowed to escape from back valve at 8*h.* 35*m.* a. m.
9.07	43.8	125	82	3.491	Smoke 20" in reaching chimney top; syphon, 0.32; filled tank at 9*h.* 55*m.* a. m.
-	45.4	127	90	2.306	
10.24	42.2	131	98	0.901	
-	41.1	135	106	2.649	
11.26	42.7	139	97	2.670	
-	44.3	142	102	2.744	
0.20	45.0	144	86	1.833	
-	45.0	148	90	1.664	
-	45.0	157	88	3.485	
1.48	44.1	159	102	2.252	Fire in full action.
-	44.9	159	95	2.229	Filled tank at 2*h.* 50*m.* p. m.
2.36	45.7	164	104	1.947	Removed clinker from grate.
-	44.1	162	120	2.501	
3.51	44.9	170	98	2.230	The first charge of coal contained one large lump, the ninth
-	46.5	176	99	2.219	was all fine, the other eight about an average.
4.40	49.5	181	98	2.236	Very little smoke from chimney to-day.
-	43.4	185	105	-	Contents of ash pit thrown on grate at 5*h.* 15*m.* p. m.; damper set to 3 inches; water 1 inch above normal level.
-	42.7	179	—11	-	Water 0.8 inch below normal level; damper entirely closed.
-	41.1	177	—10	-	Water left 0.18 inch above normal level; air port wholly closed. Experiment terminated.
-	38.9	150.5	—27	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	43.75
Ashes	65.75
Ashes behind bridge	5.906
Total ashes and clinker	115.406
Deduct wood ashes	0.286
Total waste from coal	115.120
Coke	6.75
Soot (from four burnings)	14.625

TABLE LXIII.—DEDUCTIONS FROM

Experiments on Neff's

	Nature of the data furnished by the respective tables.	1st Trial. (*Table LIX.*)	2d Trial. (*Table LX.*)
		October 14.	*October* 16.
1	Total duration of the experiment, in hours - - -	26.75	22.417
2	Duration of steady action, in hours - - - -	6.088	7.717
3	Area of grate, in square feet - - - -	14.07	14.07
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	18.75	18.75
6	Number of charges of coal supplied to grate - - -	10.0	10.0
7	Total weight of coal supplied to grate, in pounds - -	1092.75	1078.75
8	Pounds of coal actually consumed - - - -	1085.25	1071.0
9	Pounds of coal withdrawn and separated after trial - -	7.5	7.75
10	Mean weight, in pounds, of one cubic foot of coal - -	54.6875	53.9375
11	Pounds of coal supplied per hour, during steady action -	126.607	97.427
12	Pounds of coal per square foot of grate surface, per hour -	8.998	6.924
13	Total waste, ashes and clinker, from 100 pounds of coal -	11.7922	10.9835
14	Pounds of clinker alone, from 100 pounds of coal - -	5.1776	4.0103
15	Ratio of clinker to the total waste, per cent. - - -	43.906	36.513
16	Total pounds of water supplied to the boiler - - -	9196.0	8541.0
17	Mean temperature of water, in degrees Fahrenheit - -	56°.6	55°.9
18	Pounds of water supplied at the end of experiment, to restore level	38.0	36.0
19	Deduction for temperature of water supplied at the end of experiment - - - - - - -	6.0	5.0
20	Pounds of water evaporated per hour, during steady action -	1059.921	813.797
21	Cubic feet of water per hour, during steady action - -	16.958	13.021
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - - -	2.808	2.155
23	Pounds of water per square foot, by a mean of several observations - - - - - - - -	2.779	2.122
24	Water evaporated by 1 of coal, from intial temp. (a) final result - - - - - - - -	8.465	7.97
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action - - - - - - -	8.871	8.353
26	Pounds of fuel evaporating one cubic foot of water - -	7.3834	7.8419
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - - - -	59°.71	62°.9
28	Mean temp. of wet bulb thermom., during steady pressure -	52°.36	54°.5
29	Mean temperature of air, on arriving at the grate - -	237°.0	190°.3
30	Mean temperature of gases, when arriving at the chimney -	316°.5	330°.1
31	Mean temperature of steam in the boiler - - -	234°.67	232°.8
32	Mean temperature of attached thermometer - - -	55°.36	58°.225
33	Mean height of barometer, in inches - - -	30.236	29.946
34	Mean number of volumes of air in manometer - -	4.813	4.988
35	Mean height of mercury in manometer - - -	0.5764	0.5586
36	Mean height of water in syphon draught gauge, in inches -	0.3883	0.3943
37	Mean temperature of dew point, by calculation - -	44°.38	46°.585
38	Mean gain of temperature by the air, before reaching grate -	177°.29	127°.4
39	Mean difference between steam and escaping gases - -	81°.83	97°.71
40	Water to 1 of coal, corrected for temperature of water in cistern	8.465	7.97
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - - -	9.7422	9.1779
42	Pounds of water, from 212°, to 1 cubic foot of coal - -	532.29	495.03
43	Water, from 212°, to 1 pound of combustible matter of the fuel - - - - - - - -	11.0446	10.3093
44	Mean pressure, in atmospheres, above a vacuum - -	1.4882	1.4432
45	Mean pressure, in pounds per square inch, above atmosphere	7.2104	6.5456
46	Condition of the air plates at the furnace bridge - -	Closed.	Open
47	Inches opening of damper, (U. upper) - - -	U 8	U. 8

TABLES LIX, LX, LXI, LXII.

(Cumberland) coal.

3d Trial. (*Table LXI.*)	4th Trial. (*Table LXII.*)	Averages.	Remarks.
October 17.	*October* 18.		
24.25	23.883		
6.417	7.7		
14 07	14.07		
377.5	377.5		
18.75	18.75		
10.0	10.0		
1076.0	1095.5		
1073.38	1088.75		
2.62	6.75	6.755	
53.8	54.775	54.2875	
119.272	99.93	110.809	On the first day's trial, the weather was clear, and the wind northwest.
8.477	7.102	7.857	
10.4744	10.5736	10.956	
4.9032	4.0119	4.5257	
46.812	37.908	41.965	
8589.0	9162.0		
53°.6	55°.2		
67.0	483.0		
9.0	67.0		
962.91	863.5	925.032	
15.407	13.81	14.799	The greatest rapidity of evaporation occurred at the first trial, when the *flues* were clean.
2.551	2.287	2.450	
2.643	2.334		
7.993	8.3536	8.1954	The two results (1st and 4th trials) with air plate *closed* are nearly identical, as are the other two, obtained with air plate open; but the *last two* will be observed to fall considerably below the first, indicating that no economy was derived from an opening at the bridge, but the reverse.
8.974	8.641	8.3597	
7.8194	7.4818	7.6316	
60°.47	63°.77		
51°.62	53°.72		
215°.56	211°.2	213°.515	
367°.5	332°.0	336°.525	
232°.31	233°.2		
54°.44	58°.66		
29°.923	29.964		
4.8656	4.874		
0.5714	0.5705		
0.4086	0.365	0.389	
42°.06	44°.17		
166°.09	147°.43	151°.8	
139°.86	97°.18	104°.02	
7.993	8.3536	8.1954	
9.2222	9.6253	9.4419	
496.16	527.23	512.68	
10.2981	10.7634	10.6038	The difference in the evaporative effect of the unit of combustible matter, in the 1st and 4th trials, may be in part accounted for by the soot which had accumulated in three days.
1.4709	1.4781	1.4696	
6.965	7.0317	6.9334	
Open.	Closed.		
U. 12	U. 6		

No. 3.

Bituminous coal sent by Captain William Easby.

This sample of coal was accompanied by the following letter:

"WASHINGTON, *January* 13, 1843.

"SIR: I herewith send one hogshead, one tierce, and three barrels, of Cumberland coal, for the purpose of having its qualities tested. Will you be pleased to dispose of it as you think proper? The coal has been taken from a new mine called 'Coal-in-Store.' The casks are marked 'William Easby, Washington; coal from Coal-in-Store, near Cumberland, Maryland.'

"I am, sir, very respectfully, your most obedient servant,

"WM. EASBY.

"Captain B. KENNON."

In its exterior characters, this coal strongly resembles both the two samples from the same district, which have already been described. It is composed of alternating plies of a bright and a dull black color—the former belonging to the semi-crystalline or columnar portions, and the latter to the amorphous or slaty parts. The partings are perpendicular to the surfaces of deposition. These partings are frequently marked with small circular and other spots of sulphuret of iron. Fractures do not readily take the direction of the horizontal partings, so as to display the forms of organic bodies.

The specific gravity of two specimens was taken. The first gave 1.3046, and the second 1.3092; the mean of which indicates a weight in the solid coal of 81.685 pounds per cubic foot.

Eleven trials in the charge box gave the mean weight per cubic foot 53.466 pounds, or 0.6545 of the calculated weight derived from the specific gravity. It proves that 41.896 cubic feet of space will be required for the stowage of 1 ton. The moisture, determined from the two specimens above referred to, was 0.804 for the first, and 1.07 for the second; or a mean of 0.937 per cent.; 28 pounds, dried in the steaming apparatus, lost only 3 ounces, or 0.6696 per cent.

The volatile matter, other than moisture, was in the first specimen 14.811, and in the second 15.158 per cent. of the weight of raw coal.

A higher proportion of earthy matter was found in the specimen which had the highest specific gravity—the *first* giving as the mean of the two trials, differing but little from each other in result, 4.056; and the second, by two identical results, gave 6.52. Hence, of these two specimens we have the composition as follows:

	Specimen *a*.	Specimen *b*.
Moisture	0.804	1.070
Other volatile matter	14.811	15.158
Ashes	4.056	6.520
Fixed carbon	80.329	77.252
	100.	100.
Fixed to volatile combustible as	5.423 : 1	5.096 : 1

The coke is in a well-formed mass; the parts completely agglutinated, having a striated surface, silky lustre, and porous texture.

The combustion of 1,158 pounds of this sample left 97.09 pounds of waste, composed of 15.5 pounds of clinker, and 81.59 of ashes; or the whole was 8.3846 per cent. of the coal burned. The ashes lost by reincineration in the platinum capsule 12.87, and the clinker 1.143 per cent.; so that the actual quantity of incombustible matter left in the furnace was but 84.82 pounds, or 7.325 per cent. of the coal burned.

The ashes weigh 39.01 pounds per cubic foot, and the clinker 29 pounds. The latter is, in all respects, similar to that obtained from the preceding samples of coal, and bears to the total waste the relation of 15.9 per cent.

Of soot and dust, there were found in the flues 5.25 pounds, weighing at the rate of 16.68 pounds per cubic foot; and of which 47.39 per cent. was either volatile or combustible matter, and 52.61 ashes of a reddish-gray color. This, added to the waste from the furnace, makes the total waste from the coal 8.083 per cent.

The ashes of this sample (both those from the hand specimens analyzed, and those from the furnace) are almost identical in color and other sensible properties with those from the coal of Messrs. Atkinson & Templeman; the latter having only a slightly darker tint in the residue from the ashes, and a trifle lighter one from the clinker. They seem to indicate that both came from the same member of the coal series.

The time required by this coal to bring the boiler to steady action was 1.75 hour. The quantity of coke left on the grate was 18.25 pounds. Both these circumstances indicate greater difficulty in exciting and sustaining combustion than had been experienced in the preceding sample.

A trial of heating power by the oxide of lead resulted in producing of metallic lead 30.155 parts for each part of coal employed. As the moisture and earthy matter together were 7.83 per cent. of the raw coal, the quantity of combustible matter by which the reduction was effected was 92.17 per cent. Hence the *lead* to 1 of *combustible* is 32.695.

For the purposes of smith work, domestic use, the production of illuminating gas, and the manufacture of iron, the same general remarks will apply as were made in reference to the sample last described, with the additional advantage to this sample of a greater freedom from earthy matter.

TABLE LXIV.—EASBY'S

Upper damper 8 inches open; steam thrown

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam.		Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 25	4.50	78	73	116	[illegible]	79			29.99	0 348	7.07	0.07	–	–
	7 46	79	76	132	238	[illegible]			[illegible]	0 596	5.31	[illegible]	–	106.25
	7.50	79	74	130	224	78			29.99	0.523	5.34	[illegible]	–	–
	8.30	80	75	140	251	79			29 99	0.531	[illegible]	0.26	167	–
	9 00	81	75	148	263	79			29.99	0.548	5.10	0.30	604	98.60
	9.30	83	75	158	264	79	232	80	29.99	0.543	5.14	0.30	844	–
	10.00	85	77	171	263	79	232	81	29 98	0.540	5.17	0.29	1358	109.25
	10.30	87	77	186	262	79	232	83	29.98	[illegible]	[illegible]	0.30	1796	–
	11.00	89	78	196	270	79	230	84	[illegible]	0.536	5.20	0.29	2104	–
	11.30	90	77	201	272	79	230	85	29.97	0.536	5.20	0.30	2502	109.25
	P. M. 0.00	92	78	204	272	78	230	85.5	29.97	0 530	5.24	0.30	2887	–
	0.30	[illegible]	79	210	278	78	230	86	29.96	0 533	5.24	0.33	3342	104,50
	1.00	94	79	212	274	78	230	87	29.96	[illegible]	[illegible]	0.33	3667	–
	1.30	95	80	216	284	[illegible]	230	88	29.94	0.538	5.24	0.35	4087	–
	2.00	96	80	221	[illegible]	78	230	88	29.92	0.438	5.19	0.34	4347	109.25
	2.30	96	79	230	296	79	230	88	29.91	0 545	5 12	0.40	[illegible]	–
	[illegible]	97	81	222	287	79	230	89	29.90	0.527	5.30	0.36	5287	102.25
	3.30	97	82	226	279	80	230	89	29.90	[illegible]	[illegible]	0.34	5539	–
	4.00	97	83	232	274	80	229	89	[illegible]	0.527	5.30	0.33	5947	–
	4.30	97	81	236	289	80	230	89	29.88	0.533	5.24	0.35	[illegible]	112.60
	5.15	95	81	238	[illegible]	80	231	89	29.86	0.536	5.21	[illegible]	6800	–
	5.40	96	81	237	282	82	231	89	29.87	0.523	5.34	0.30	[illegible]	111 50
	[illegible]	96	81	[illegible]	278	82	232	89	[illegible]	[illegible]	5.30	[illegible]	7470	–
	[illegible]	92	80	244	280	82	232	88	[illegible]	0.535	5.22	0.36	7990	–
	7.00	95	81	247	300	82	231	88	[illegible]	0.532	5.25	[illegible]	8282	109 25
	7.30	91	80	250	298	82	231	87	[illegible]	[illegible]	[illegible]	0.27	[illegible]	–
	[illegible]	90	79.5	259	286	82	230	87	29.87	[illegible]	5.32	0.30	9281	103.75
	8.30	91	80	[illegible]	[illegible]	82	230	86.5	29.88	0.512	5.44	0.25	9698	–
	8.45	92	80	266	248	82	226	86	29.88	0.508	5.58	0.23	9990	–
	A. M.													
Sept. 26	6.30	76	74	206	206	82	224	80	29.85	0.482	[illegible]	0.14	9996	–
	6.55	81	74	210	204	82	221	80	[illegible]	0.447	6.10	0.13	10367	–

The period of steady action this day extends from 9h. 43m. a. m. to 7h. 52m. p. m.; coal supplied, 662.25 pounds; water to the boiler in that time, 8,073.7 pounds; water to one of coal for the same period, (approximate,) 9.963.

(CUMBERLAND) COAL.

into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	71.0	38	— 7	-	Water 0.63 inch below normal level; fire kindled at 5*h.* 11*m.* a. m.
7.50	73.5	53	— 1	-	Wood consumed, 295.5 pounds; commenced charging with coal.
-	72.1	51	— 6	-	Second weight removed from valve, and steam blows off; damper set at 8 inches.
-	73.2	60	+20	0.664	Air plates opened at 8*h.* 15*m.* a. m.; morning clear; wind SW., light.
8.46	72.8	67	31	1.785	
-	72.2	75	32	1.801	Placed 28 pounds of this coal in drying apparatus.
9.42	74.4	89	31	2.749	
-	73.8	99	30	1.801	But little smoke at chimney top after charging.
-	74.6	107	40	2.124	Cold oil put in tube in boiler for thermometer.
11.23	73 0	111	42	2.109	Filled tank at 11*h.* 35*m.* a. m.
-	73.8	112	42	1.722	Commenced drawing gases at 11*h.* 40*m.* a. m.; drew in 30 minutes 100 cubic inches, which gave water 1.52 grain; carbonic acid, 4.71 grains; oxygen, 11.87 cubic inches;
0.25	74.7	116	48	2.199	temperature of bath, 88°; dew point, by observation, 72°;
-	74.7	118	44	2.252	by calculation at same time and place, 73°.
-	75.9	121	54	2.225	Air plates closed at 1*h.* 20*m.* p. m.; commenced drawing
1 40	75.7	125	39	1.377	gases a second time at 1*h.* 54*m.* p. m.; drew in 34 min-
-	74 2	134	66	1.806	utes, 100 cubic inches; which gave water, 1.16 grain; car-
2.46	76.8	125	57	3.173	bonic acid, 3.72 grains; oxygen, 11.76 cubic inches;
-	78.2	131	49	1.335	temperature at bath, 90°.
-	79.6	135	45	2.162	
4.14	76.8	139	59	1.733	Dew point, by observation, (at 4*h.* 14*m.* p. m.,) 72°.
-	77 3	148	50	1.858	Filled tank at 5*h.* 25*m.* p. m.
5 38	77.1	141	51	2.619	
-	77.1	142	46	2.050	
-	76.6	158	48	2.172	
6.57	77.3	152	69	2 129	
-	76.9	159	67	2.543	Second weight taken from back valve.
7.52	76.5	162	58	2.719	
-	76.9	170	32	-	Contents of ash pit thrown on grate.
-	76.6	174	20	-	Damper at 4 inches; water 0.75 inch above normal level.
-	72.5	128	—16	-	Water in boiler adjusted.
-	71.4	129	—17		

RESIDUA.

	Pounds.		Pounds.
Clinker - - - -	15.50	Coke - - - - -	12.25
Ashes - - - -	78.50		
Ashes from behind bridge -	4.00	Soot - - - - -	5.25
Total ashes and clinker -	98.00		
Deduct wood ashes - -	0.907		
Total waste from coal -	97.093		

TABLE LXV.—DEDUCTIONS FROM TABLE LXIV.

Experiments on Easby's (Cumberland) coal, from Coal-in-Store mine.

	Nature of the data furnished by the preceding table.	Trial. (*Table LXIV.*)
		September 25.
1	Total duration of the experiment, in hours	26.083
2	Duration of steady action, in hours	10.15
3	Area of grate, in square feet	14.07
4	Area of heated surface of boiler, in square feet	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75
6	Number of charges of coal supplied to grate	11.0
7	Total weight of coal supplied to grate, in pounds	1176.25
8	Pounds of coal actually consumed	1158.0
9	Pounds of coal withdrawn and separated after trial	18 25
10	Mean weight, in pounds, of one cubic foot of coal	53.466
11	Pounds of coal supplied per hour, during steady action	84.9507
12	Pounds of coal per square foot of grate surface, per hour	6.037
13	Total waste, ashes and clinker, from 100 pounds of coal	8.3846
14	Pounds of clinker alone, from 100 pounds of coal	1.326
15	Ratio of clinker to the total waste, per cent.	15 815
16	Total pounds of water supplied to the boiler	10357.0
17	Mean temperature of water, in degrees Fahrenheit	80°.5
18	Pounds of water supplied at the end of experiment, to restore level	352 0
19	Deduction of temperature of water supplied at the end of experiment	36.0
20	Pounds of water evaporated per hour, during steady action	795.438
21	Cubic feet of water per hour, during steady action	12.726
22	Pounds of water per square foot of heated surface per hour, by one calculation	2 107
23	Pounds of water per square foot, by a mean of several observations	2.137
24	Water evaporated by one of coal, from initial temperature (a) final result	*8.913
25	Water evaporated by one of coal, from initial temp. (b) during steady action	9.363
26	Pounds of fuel evaporating one cubic foot of water	7.0122
27	Mean temperature of air entering below ash pit, during steady pressure	91°.96
28	Mean temperature of wet bulb thermometer, during steady pressure	79°.13
29	Mean temperature of air, on arriving at the grate	211°.65
30	Mean temperature of gases, when arriving at the chimney	276°.78
31	Mean temperature of steam in the boiler	230°.7
32	Mean temperature of attached thermometer	86°.03
33	Mean height of barometer	29.927
34	Mean number of volumes of air in manometer	5.226
35	Mean height of mercury in manometer	0.5343
36	Mean height of water in syphon draught gauge	†0.3336
37	Mean temperature of dew point, by calculation	75°.51
38	Mean gain of temperature by the air, before reaching grate	119°.69
39	Mean difference between steam and escaping gases	48°.5
40	Water to one of coal, corrected for temperature of water in cistern	8 8802
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	10.0183
42	Pounds of water, from 212°, to one cubic foot of coal	535.64
43	Water, from 212°, to one pound of combustible matter of the fuel	10.9358
44	Mean pressure, in atmospheres, above a vacuum	1.4226
45	Mean pressure, in pounds per square inch, above atmosphere	6.242
46	Condition of the air plates at the furnace bridge	‡Open & closed.
47	Inches opening of damper	Upper 8.

* In nearly all the Cumberland coals, it appears that the water to one of coal, by the calculation for a final result, is less than that during the assumed period of steady action. This arises, no doubt, from over estimating the weight left on the grate at the termination of that period. The large quantity of waste then filling the grate may have very naturally led to this result.

† By a preceding discussion, (see page 20, note,) the velocity of the motion of air at ordinary temperature, when the gauge is .333, should be about 12.08 feet per second.

‡ The air plates were kept open for about half the period of this trial.

No. 4.

Bituminous free-burning coal from Atkinson & Templeman, of Cumberland, Maryland.

In reply to an inquiry relative to the origin of this sample, the following information was received :

"CUMBERLAND, MARYLAND, *March* 16, 1844.

"DEAR SIR : Your favor of the 13th instant, in regard to our coal, came to hand in due time, and we hasten to reply.

"The sample to which you allude was taken from a vein 9 feet some inches in thickness, on the eastern slope of Dan's mountain, about 40 feet below the surface of the earth, on a stream known by the name of Clary's run, two miles south of the national road. The vein is solid, and without slate, and now worked so as to be mined in lumps. The sample sent was taken direct from the mines, and must have been mined from two to three weeks before received by you.

"We are, dear sir, your obedient servants,

"ATKINSON & TEMPLEMAN.

"Professor WALTER R. JOHNSON,
"*Philadelphia.*"

The character of this coal is that of a mixed columnar and slaty mass; the former being possessed of a deep shining jet black color, a friable consistence, and occasionally a striated surface, with a semi-conical radiated arrangement of the striæ. The main partings are perpendicular to the surfaces of deposition; but the cross cleats, or partings, are oblique to both. Beautifully iridescent surfaces are occasionally met with. Thin plies of sulphuret of iron are visible in some specimens; and specks of the same in an efflorescent state, having developed the sulphate of iron, are apparent after some twelve or fourteen months' exposure to the air.

The specific gravity of two specimens was found to be, respectively, 1.322 and 1.305; from the mean of which the calculated weight of a cubic foot is 82.09 pounds.

The mean weight of the same bulk of coal, as weighed in twenty-two charges of 2 cubic feet each, was found to be 52.92 pounds, or 0.6446 of the computed weight. Hence, the bulk required for the stowage of 1 ton is 42.328 cubic feet.

This coal appears to have very little tendency to absorb moisture. In the analysis of the first of the above-mentioned specimens, it gave but 0.53 per cent. of loss after heating to 300°; the other specimen weighed exactly the same *after* drying as it did *before*.

A trial of 28 pounds in the steam apparatus over the boiler, for two days, caused the expulsion of only 2 ounces of moisture, or 0.446 per cent.

The volatile matter, other than moisture, expelled in coking at a bright red heat, was found to be, in one specimen, coked with but moderate rapidity, 18.586 per cent.; in the other specimen, it was found, by a rapid application of heat, to be 17.411 per cent.

On incinerating the first specimen, the earthy matter was found to be 5.653, that of the second 5.239; the one possessing the highest specific gravity giving (as most commonly happens) the greater proportion of ashes.

From these data, it appears that the two specimens are composed as follows:

	Specimen *a*.	Specimen *b*.
Of moisture - - - - - - -	0.530	0.000
Of other volatile matter - - - - -	12.536	17.411
Of earthy matter - - - - - -	5.653	5.239
Of fixed carbon - - - - - -	81.281	77.350
	100.	100.

Hence, the *fixed carbon* left, after slowly coking *a*, was 6.483 times as heavy as the volatile matter expelled; and, after rapidly coking *b*, it was but 4.442 times as heavy. Hence, the advantage of slow coking for economical purposes, as will be further developed hereafter.

In the two trials of this coal under the steam boiler, there were consumed 2,318.25 pounds. From this were derived 183.708 pounds of *waste*, made up of 133.958 of ashes, and 49.75 of clinker. Hence the mean per centage of waste is 7.925; that of the ashes being 5.779, and that of the clinker 2.146.

Reincinerating the *ashes* caused them to lose 11.85 per cent. of their weight, and the *clinker* 0.485 per cent.; so that the former is reduced to 5.094, and the latter to 2.042 per cent. of the weight of coal; or the total earthy residuum thus derived from the furnace is 7.136 per cent.

There were obtained from the flues after two trials 11¼ pounds of soot; of which 10.6 per cent. were found to be matter volatile at a red heat, being doubtless salts of ammonia; 49.5 combustible carbon, and 39.9 a light-colored ash, very similar to that derived from the reincineration of the *ashes*. Of the carbon, a considerable portion must have been derived from the wood used in heating up the apparatus during the experiments; of which 502¼ pounds had been employed. The coal, therefore, gave for total waste 7.334 per cent. of absolutely incombustible matter.

A trial of this coal, by separating nearly equal small fragments from forty specimens of the sample, was made, in order to ascertain the practicability of deciding by this means the average constitution of the coal. The mixture of these fragments was completely pulverized.

When thoroughly dried, it lost - - - -	0.508	per cent.
When coked to bright cherry red heat, it lost in addition	15.532	"
When completely incinerated, it left of light pink-colored ashes - - - - - - - -	10.372	"
And showed, of course, the amount of fixed carbon to be	73.588	"
	100.	

From this, it appears that the fixed carbon is 4.738 times the weight of the volatile combustible.

The clinker is mostly in small fragments of a light brown passing into a yellow color. The tendency to vitrification is very moderate, and is confined to the darker colored portions. The rest appears to be adhering masses of slaty fragments, constituting the larger portion. It manifests no tendency to adhere to the grate bars. The ratio of clinker to the total

waste is but 20.8 per cent. The color of the pulverized and reincinerated clinker is a light reddish brown; of the *ashes*, a much lighter tint of red; and from the soot, ashes of a still lighter color were obtained. The clinker weighs but 31.62, the ashes 38.92, and the soot 15.77 pounds per cubic foot.

The time required for this coal to bring the boiler to a uniform rate of evaporation, was in the first trial 0.75, and in the second 1.216 hour, or a trifle less, on an average, than one hour from the time when the charging commenced.

The weight of coke left unburnt was in the first trial but 4.375, and in the second only 5.875 pounds; while that left in the clinker and ashes amounted, as above shown, to only 0.789 of one per cent. All these facts indicate great facility in commencing and continuing the ignition.

The trials of this coal in both the smith shops gave great satisfaction. Sixty pounds of it in the chain shop were found sufficient to make eight links of a chain cable formed of iron $1\frac{1}{16}$ inch in diameter; and the same weight again tried on a chain $1\frac{3}{8}$ inch in diameter was found sufficient to make eighteen links. It makes a dense and hot fire, with moderate flame.

In the anchor shop, it was found to make a hollow fire of moderate size, strong, and durable. The only circumstance detracting at all from its value was, that the cinder was rather too bulky, tending somewhat to obstruct the tuyeres.

As a fuel for domestic purposes, it possesses on the one hand a flame abundantly sufficient to give cheerfulness to the aspect of a parlor fire, and, on the other, a durability approximating that of some of the lighter anthracites. The proportion of gas is too small to render it available for illuminating purposes—especially where it comes in competition with coals of the highly bituminous class, as those of Pittsburg, of Richmond, of Nova Scotia, or of Great Britain.

As a furnace coal, for the manufacture of iron, it will be found among the best of the bituminous class, since, either with or without previous coking, it may be very advantageously employed in the blast furnace. It is very similar in constitution to the furnace coals of Merthyr and Llanelly, in Wales, with the exception of possessing a greater proportion of earthy matter.

A single trial for heating power by the oxide of lead of specimen *b*, above referred to, (having the lowest specific gravity, and the least of earthy matter, resulted in giving 28.49 times its weight of metallic lead. Deducting the weight of earthy matter, this would be 30.06 parts of lead to one of combustible.

The sample of coal in a box accompanying this, and consisting of less than 200 pounds, stated to be from the "Forks of Jennings's run," which are 6¾ miles above Cumberland, was too small in quantity for a trial under the steam boiler.

Its character is that of a friable coal of columnar structure, falling mostly into slack, having a shining jet black color, and being much more free from slaty matter than most of the samples of coal from the Cumberland district which have fallen under my observation. It seems to have been carefully selected, or at least much more skilfully mined than generally happens in that region.

Sixty pounds of it in the chain shop were found adequate to the making

of eight links of a chain 1$\frac{1}{16}$ inch in diameter. It was, consequently, equal in strength to the other samples sent by the same proprietors.

In the anchor shop it was found very favorable for the performance of small work, very pure, making a strong heat, but altogether unsuited for forming a hollow fire.

In an office grate, a portion, in a rather too fine state for such application, was found to take fire promptly when laid on a rather dull anthracite fire, burning with little or no smoke, and with a flame of moderate length. As the amount of vaporizable matter is far less than in many highly bituminous coals, it exhibits a prompt ignition, and none of that smouldering apathy which the latter generally display when first heated upon the grate.

The specific gravity of Jennings's run coal is 1.3092, which is identical with that of one specimen from the large sample. Its volatile matter was 17 per cent.; also nearly approximating the weight of the same material found in that specimen.

Its earthy matter was 5.53 per cent., or a very little above the mean of the two specimens above referred to. Hence the ratio of the volatile matter to the fixed carbon is one to 4.556. The calculated weight of a cubic foot is 81.83 pounds.

The coal is very friable, being composed almost wholly of columnar plies, separated by thin films of pyritous matter, which easily effloresces, developing white lines of sulphate of iron. A specimen, which has been fourteen months in my possession, is already disintegrating from this cause, and falling into powder.

I have referred above to the relation of the sample of coal now under consideration to some of those found at certain celebrated localities in Wales. The same relationship may, in general, be traced between all the samples of free-burning coals both of Maryland and Pennsylvania, and those of some one or other of the great mining and iron manufacturing districts of that country. To facilitate comparisons, I offer the following condensed view of the results of very numerous experiments on the proximate composition of coals used at some of the most celebrated of those establishments. The experiments are those of Mr. David Mushet, and are contained in his valuable work on iron and steel. The coals referred to one locality were mostly from different beds, or from different plies of the same bed. They are generally used at forges, rolling mills, and blast furnaces, for the manufacture of iron.

The series in the table commences with such as are rather more bituminous than any of the free-burning class describled in this report, and proceeds with those of less and less bituminousness, until it reaches the true anthracites, containing about the same amount of volatile matter as that of Lyken's valley, heretofore described.

The table shows in part the remarkable variety of materials found in the great Welsh coal field, and the resemblance which it bears to the southern anthracite field of Pennsylvania, which, as elsewhere stated, is now known to afford bituminous coal at one extremity, and pure anthracite at the other.

Tabular view of the proximate composition of Welsh furnace coals.

Locality at which each coal is mined or used.	Number of varieties analyzed from each locality to furnish the average composition.	Average composition in			
		Volatile matter.	Fixed carbon.	Earthy matter.	Fixed to 1 of volatile combustible.
(1.) Blaenavon iron works - - -	4	27.122	69.597	3.281	2.56
(2.) Clydach, or Llanelly works - -	7	21.813	75.598	2.589	3.46
(3.) Nantyglo - - - -	4	17.210	79.803	2.987	[illegible]
(4.) Ebby vale - - - -	7	16.707	79.847	3.446	4.78
(5.) Tredegar - - - -	9	15.603	80.056	4.341	5.13
(6.) Bute and Rhymney, Glamorganshire -	9	14.797	82.087	3.166	[illegible]
(7.) Plymouth and Duffryn, near Merthyr Tidvil	8	14.430	82.411	3.159	5.71
(8.) Sir Howy - - - -	8	14.149	80.845	5.006	5.71
(9.) Bute - - - - -	7	13.941	81.937	4.122	5.86
(10.) Bowlais - - - -	10	12.176	85.321	2.503	7.01
(11.) Penn-y-darran - - - -	8	11.139	86.111	2.750	7.73
(12.) Aberdare, Glamorganshire - -	9	10.330	85.990	3.680	[illegible]
(13.) Neath Abbey - - - -	6	8.516	87.470	4.014	10.27
(14.) Cyfarthfa and Ynnis - - -	5	8.091	89.753	2.156	11.09
(15.) Hirwain, Glamorganshire - -	4	7.982	89.091	2.927	11.17
(16.) Crane's Ynliscydwn - - -	3	7.420	89.002	3.578	12.00
(17.) Ystal-y-Fera - - - -	9	6.587	91.913	1.500	13.95

General exterior and other characters of the coals.

glance coal.

(7.) Structure either mixed of reedy and granular, or wholly granular; very bright and shining; concentric circles sometimes are apparent at the fractures.

(8.) Forms generally rhomboidal; structure granular; mineralized charcoal intermixed with reedy laminæ; cross partings more or less irregular.

(9.) Structure variable; reedy and granular intermixed; sometimes crystalloid, specular, glance, or anthracitous.

(10.) Either bright, reedy, in regular laminæ, or intersected at right angles by partings producing brittleness; color sometimes dull black, having no proper cleavage; at others, the aspect is that of beautiful glance, having minute shining laminæ oblique to the surfaces of deposition.

(11.) Structure sometimes compact, minutely laminated. Some varieties have a reediness oblique to the bed; some are graphitic in appearance, and others partly bituminous and partly anthracitous.

(12.) Several of these varieties are entirely anthracitous in character, and undergo no change of form in coking; others have the usual characteristic of dry bituminous coals.

(13.) All these varieties are true anthracites; structure slaty; color brilliant black.

(14.) Some of these are decidedly anthracitous, others contain bituminous cement between the plies, and others still are entirely bituminous. This is, indeed, a *transition* coal.

(15.) Regularly crystallized, granular, or shining, without regular cleavages; surfaces sometimes plumbaginous.

(16.) Bright, shining, pitchy; grows more brilliant by pulverizing.

(17.) All these are true anthracites, with the ordinary characters pertaining to that class.

TABLE LXVI.—ATKINSON'S &

First trial—upper damper 8 *inches open ; air plates open ;*

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 21	5.10	74	70	150	132	77	115	75	30.24	0.354	7.01	0.01	-	-
	7.00	76	71	144	210	77	158	74	30.23	0.375	6.82	0.20	-	-
	8.15	85	78	166	241	77	226	77	30.24	0.549	5.06	0.25	-	100.75
	8.30	80	74	171	245	77	232	77	30.24	0.555	5.02	0.22	-	-
	9.00	80	74	178	274	77	229	78	30.24	0.551	5.06	0.38	247	106.75
	9.30	80.5	74.5	198	288	77	231	80	30.22	0.554	5.03	0.35	937	-
	10.00	83	76	205	296	77	232	80	30.21	0.550	5.08	0.35	1374	101.00
	10.35	84	77	216	311	79	232	81	30.20	0.558	5.00	0.40	2070	-
	11.00	86	78	226	306	79	232	82	30.17	0.555	5.03	0.36	2417	99.00
	11.25	87	78	234	302	79	232	82	30.17	0.572	4.86	0.40	2839	-
	P. M. 0.00	88	79	246	300	79	232	83.5	30.17	0.572	4.86	0.42	3551	98.00
	0 30	89	80	255	304	79	232	84	30.16	0.569	4.89	0 44	4025	-
	1.00	92	81	260	291	79	230	85	30.15	0.538	5.20	0.30	4634	104.00
	1.30	93	81	264	288	79	230	86	30.12	0.536	5.21	0.28	5113	-
	2.00	95.5	82	268	292	79	230	86.5	30.11	0.545	5.12	0.25	5411	94.50
	2.30	94	81	272	280	80	230	87	30.10	0.535	5.22	0.29	5916	-
	3.00	96	83	274	288	81	230	88	30.09	0.542	5.15	0.28	6319	-
	3 30	96	82	274	299	81	230	88	30.07	0.549	5.08	0.30	6749	106.25
	4.05	96	82	274	306	81	230	88	30.07	0.543	5.14	0.30	7339	-
	4.30	95	82	276	299	79	230	89	30.06	0.539	5.18	0.30	7667	112.75
	5.00	94	82	278	299	79	230	88	30.06	0.548	5.10	0.32	8089	-
	5.30	96	82	286	293	79	230	88	30.06	0.539	5.18	0.30	8527	110.00
	6.00	92	81	289	290	79	230	88	30.05	0.535	5 22	0.28	8967	-
	6.30	92	81	292	301	79	230	86	30.05	0.541	5.16	0.26	9305	115.25
	7.00	94	82	295	306	80	229	86	30.05	0.530	5.27	0.23	9907	-
	7.10	92	81	304	275	80	226	86	30.05	0.516	5.40	0.27	10347	-
	A. M.													
Sept. 22	4.56	79	73	224	206	80	220	80	30.01	0.453	6.02	0.13	10350	-
	5.30	77	73	222	204	80	214	79	30.00	0.390	6.66	0.11	10970	-

The period of steady action is from 9*h.* a. m. to 6*h.* 19*m.* p. m.=9*h.* 19*m.*; coal supplied to the grate, 941.25 lbs.; water to the boiler, 8,934 lbs.; water to 1 of coal, 9.491; 20 sets of observations taken during the period.

TEMPLEMAN'S (CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was ... in grate.	Dew point, by calculation.	Gain of temperature by ...	... ture between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 68 feet.
h. m.					
-	68.2	76	+17	-	Water 0.94 inch below normal level; commenced firing at 5*h.* 23*m.*; wind SW., light; clear.
-	68.9	66	58	-	Water 0.6 inch below normal level.
8.15	[illegible]	61	15	-	Wood consumed, 399.25 lbs.; commenced charging with coal.
-	71.7	91	13	-	Steam blows off; coal ignites promptly; syphon rose to 0.32 after taking off second weight.
9.00	71.7	96	46	[illegible]	Air plates opened at 8*h.* 50*m.*; damper reduced to 8 inches.
-	72.3	117.5	57	2.656	
10.00	72.6	122	64	2.315	
-	74.7	132	79	3.161	A small discharge of thin brown smoke appears at chimney top, on stoking.
11.00	75.5	140	74	2.206	Fourth charge of coal in lumps.
-	75.2	147	70	2.683	Filled tank.
11.50	76.3	158	66	3.238	Commenced drawing gases at 0*h.* 28*m.*; drew in 36 minutes 100 cubic inches, which gave water 2.15 grains, carbonic acid 4.53 grains, and oxygen 14.07 cubic inches.
-	77.4	166	72	2.511	
0.45	[illegible]	168	61	3.226	Steam allowed to escape from both valves at 0*h.* 30*m.* p. m.
-	77.8	171	66	2 538	Back valve loaded with small additional weights.
2.00	78.5	172.5	62	1.584	
-	77.5	178	50	2 675	Very little smoke from chimney, and only when charging or stoking.
-	79.8	178	58	3.135	
3.10	78.4	178	69	3.278	Eighth charge in lumps, with some fine coal.
-	78.4	178	76	3.679	
4.10	76.7	[illegible]	69	2.085	Filled tank; ninth charge, one large lump with fine coal.
-	78.9	184	69	2.226	
5.18	[illegible]	190	63	2.321	Placed 28 lbs. of this coal in drying apparatus.
-	78.0	197	60	2.331	
[illegible]	[illegible]	200	71	1.791	Eleventh charge, lumps with fine coal.
-	76.9	201	77	3.189	Air plates closed, and contents of ash pit thrown on grate.
-	[illegible]	212	49	-	Water in boiler left at 1 inch above normal level; damper reduced to 4 inches.
-	70.7	145	—14	-	Water found 1.45 inch below normal level.
-	71.4	146	—10	-	Water in boiler adjusted for the present temperature.

RESIDUA.

	Pounds.
Clinker	24.50
Ashes	62.50
Ashes from behind bridge	6.00
	[illegible]
Deduct wood ashes	1.228
Total waste from coal	91.772
Coke, including a portion from behind the bridge	4.375

TABLE LXVII.—ATKINSON &

Second trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.
	h. m. A. M.												
Sept. 22	6.00	79	73	218	207	81	216	78	30.00	0.384	6.71	0.12	-
	6.42	80	74	199	272	81	230	80	30.03	0.548	5.14	0.21	-
	7.00	80	74	200	240	81	232	80	30.05	0.540	5.17	0.26	-
	7.30	81	74	196	288	81	232	80	30.05	0.546	5.17	0.30	180
	7.55	80	75	195	310	81	232	80	30.05	0.550	5.04	0.38	494
	8.30	84	75	203	327	77	232	81	30.05	0.558	5.00	0.40	1044
	9.00	85	76	216	313	77	232	83	30.06	0.538	5.20	0.28	1384
	9.30	87	76	228	312	77	231	85	30.05	0.544	5.13	0.32	1974
	10.00	86	74	242	318	77	231	86	30.06	0.538	5.22	0.34	2628
	10.30	87	76	254	324	78	231	86	30.05	0.532	5.25	0.31	3189
	11.00	87	76	260	309	78	232	85.5	30.05	0.556	5.02	0.36	3560
	11.25	87.5	76	262	331	78	232	86	30.05	0.554	5.03	0.32	3956
	P. M. 0.00	87	77	272	318	80	232	85	30.04	0.548	5.10	0.30	4519
	0.30	86	76	276	318	80	231	84	30.04	0.555	5.02	0.31	5191
	1.00	86	76	281	323	80	232	84	30.04	0.555	5.02	0.32	5610
	1.30	85	75	285	331	80	232	84	30.04	0.555	5.02	0.34	6297
	2.00	86	75.5	290	324	80	232	83	30.04	0.554	5.03	0.34	6716
	2.30	84	74	291	330	80	232	83	30.04	0.555	5.02	0.35	7036
	3.00	84	74	294	328	80	231	82	30.04	0.550	5.08	0.30	7714
	3.30	82	73	296	330	80	231	81	30.03	0.553	5.04	0.34	8125
	4.00	82	73	298	328	79	232	81	30.03	0.551	5.06	0 30	8615
	4.30	81	73	306	310	79	231	80	30.04	0.555	5.02	0.34	9109
	5.00	80	72	310	315	79	231	80	30.04	0.558	5.00	0.35	9520
	5.30	80	72	310	331	79	231	79	30.04	0.558	5.00	0.35	10199
	5.45	79	71	310	306	79	230	79	30.04	0.543	5.14	0.25	10667
Sept. 23	A. M. 5.28	72	67	212	198	79	215	75	30.08	0.402	6.54	0.13	10673
	6.08	73	67	211	198	80	214.5	73	30.08	0.353	7.02	0.15	11258

Period of steady action, from 8*h*. 40*m*. a. m. to 5*h*. p. m. = 8*h*. 20*m*. Coal supplied to grate, 875.5 lbs ; water to boiler, 8,362.66 lbs.; water to 1 of coal, 9.552.

TEMPLEMAN'S (CUMBERLAND) COAL.

...thrown into chimney, and small furnace in action.

Weight of charge of coal.	Time each charge was on grate.	...MARKS.—Grate surface 14.07 square feet; ...ngth of circuit of heated gases 131 feet; height ...chimney 63 feet.
	h. m.	
-	-	...ing clear; wind NW., light. ...menced firing; water in boiler 0.12 inch be-
103.25	6.42	...w normal level; both valves double weighed, ...d consumed, 103 lbs.; commenced charging ...th coal.
-	-	... second weight from safety valve; steam blows
100.25	7.12	
-	-	...per set at 8 inches at 7*h*. 40*m*. a. m.
-	-	...l tank at 8*h*. 8*m*.; steam allowed to escape ...m both valves.
100.75	8.40	
-	-	
117.00	9.47	...fourth charge consists of one large lump, and ...rest fine coal.
-	-	...l NE., brisk; clear; two small additional ...ights put on front valve. ...menced drawing gases at 11*h*. 5*m*. a. m.; ...w in 27 minutes 100 cubic inches, which ...ve water 1.36 grain, carbonic acid 6.05 grains, ...ygen 11.03 cubic inches; dew point, by ob- ...vation, 70°.
102.75	10.57	
-	-	
112.75	11.57	...perature of bath 84°.5; filled tank at 11*h*. ...m. a. m.
-	-	...becoming overcast at 0*h*. 15*m*. p. m.; the ...th charge, large lumps and fine.
105.00	0.50	...l NE., brisk; cloudy.
-	-	
105.75	1.40	
-	-	...ly.
112.00	3.00	
-	-	
100.50	4.00	28 lbs. of coal placed in drying apparatus ...igh, after two days' drying, 27 lbs. 14 oz.
-	-	
109.75	5.00	
-	-	...ents of ash pit thrown on grate, and damper ...uced to 4 inches.
-	-	...r in boiler left at 1 inch above normal level.
-	-	...r found 1.1 inch below normal level.
-	-	...r in boiler adjusted.

RESIDUA.

	Pounds.		*Pounds.*
Clinker - - - -	25.25	Total waste of coal - -	91.934
Ashes - - - -	61.00		
Ashes behind bridge - -	6.00	Coke - - -	6.875
Total clinker and ashes -	92.25		
Deduct wood ashes - -	.316	Soot, (2 burnings) - - -	11.5

TABLE LXVIII.—DEDUCTIONS

Experiments on Atkinson & Temple.

	Nature of the data furnished by the respective tables.	1st Trial. (*Table LXVI.*)	2d Trial. (*Table LXVII.*)
		September 21.	*September 22.*
1	Total duration of the experiment, in hours	24.332	24.133
2	Duration of steady action, in hours	9.317	8.33
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	11.0	11.0
7	Total weight of coal supplied to grate, in pounds	1148.75	1179.75
8	Pounds of coal actually consumed	1144.375	1173.875
9	Pounds of coal withdrawn and separated after trial	4.375	5.875
10	Mean weight, in pounds, of one cubic foot of coal	52.226	53.625
11	Pounds of coal supplied per hour, during steady action	101.028	105.184
12	Pounds of coal per square foot of grate surface, per hour	7.18.	7.475
13	Total waste, ashes and clinker, from 100 pounds of coal	8.0919	7.8315
14	Pounds of clinker alone, from 100 pounds of coal	2.1087	2.1416
15	Ratio of clinker to the total waste, per cent.	26.295	27.346
16	Total pounds of water supplied to the boiler	10970.0	11258.0
17	Mean temperature of water, in degrees Fahrenheit	78°.5	79°.3
18	Pounds of water supplied at the end of experiment, to restore level	620.0	500.0
19	Deduction for temperature of water supplied at the end of experiment	80.0	64.0
20	Pounds of water evaporated per hour, during steady action	958.923	1003.56
21	Cubic feet of water per hour, during steady action	15.34	16.057
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.54	2.649
23	Pounds of water per square foot, by a mean of several observations	2.541	2.641
24	Water evaporated by 1 of coal, from initial temperature (a) final result	9.516	9.502
25	Water evaporated by 1 of coal, from initial temperature (b) during steady action	9.491	9.552
26	Pounds of fuel evaporating one cubic foot of water	6.5679	6.5776
27	Mean temperature of air entering below ash pit, during steady pressure	89°.95	84°.325
28	Mean temp. of wet bulb thermom., during steady pressure	79°.55	74°.725
29	Mean temperature of air, on arriving at the grate	249°.33	268°.5
30	Mean temperature of gases, when arriving at the chimney	292°.95	322°.65
31	Mean temperature of steam in the boiler	230°.67	231°.55
32	Mean temperature of attached thermometer	84°.52	82°.875
33	Mean height of barometer, in inches	30.132	30.0445
34	Mean number of volumes of air in manometer	5.085	5.065
35	Mean height of mercury in manometer, in atmospheres	0.5483	0.5508
36	Mean height of water in syphon draught gauge, in inches	0.3205	0.3195
37	Mean temperature of dew point, by calculation	76°.61	71°.365
38	Mean gain of temperature by the air, before reaching grate	159°.38	184°.175
39	Mean difference between steam and escaping gases	66°.35	82°.316
40	Water to 1 of coal, corrected for temperature of water in cistern	9.4825	9.4686
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	10.707	10 6913
42	Pounds of water, from 212°, to 1 cubic foot of coal	559.18	573.32
43	Water, from 212°, to 1 pound of combustible matter of the fuel	11.6484	11.5997
44	Mean pressure, in atmospheres, above a vacuum	1.4597	1.4626
45	Mean pressure, in pounds per square inch, above atmosphere	6.79	6.8325
46	Condition of the air plates at the furnace bridge	Open.	Closed.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

FROM TABLES LXVI, LXVII.

man's coal, (Cumberland, Maryland.)

Averages.	Remarks.
5.125	The weight of unburnt coke left by this coal is less than one twenty-second part as much as remained of some of the anthracites, when the fire became extinct.
53.[illegible]	
103.106	
7.827	
7.9622	
2.1251	
26.825	
981.241	
15.698	
2.5[illegible]	
9.[illegible]09	A very close approximation between this and the following line will be observed.
9.521	
6.5727	
258°.91	
307°.80	
0.32	
171°.777	
75°.333	
9.4755	
10.6991	The two trials of this coal give a remarkable coincidence of results, as well as a very high average amount of evaporation. It is, indeed, the highest result obtained during the research.
566.25	
11.6241	
1.4612	
6.8112	
–	The burning with open air plate seems to have produced but little effect on the efficiency of this coal.

No. 5.

Bituminous coal from the mines of Easby & Smith, above Cumberland, delivered for use at the navy yard, Washington; selected from a boat load, by Captain Easby.

This sample of coal was stated to be from the mines called "Coal-in-Store," the same from which a preceding sample sent by Captain Easby was also taken.

In its exterior characters, this sample strongly resembles that coal. In some cases, however, it exhibits larger portions of carbonaceous matter on the surfaces of deposition. A radio-striated appearance occasionally occurs, and the alternating plies of columnar or crystalloid, and slaty or amorphous coal, are preserved, and often strongly marked.

The main partings are perpendicular to the surfaces of deposition; and cross partings at different angles to the same surfaces, giving the impression of a forcible bending of the plies, are not uncommon.

The specific gravity of one specimen which was analyzed, was found to be 1.4023, and of another 1.3628; the mean of which gives the calculated weight of one cubic foot of this coal, 86.41 pounds.

Forty-eight trials in the charge box gave the weight of one cubic foot 53.174 pounds; being 0.6153 of the calculated weight from specific gravity. The space required for stowing one gross ton will be 42.126 cubic feet. The minimum weight of a cubic foot was 48, and the maximum 55.5 pounds, as will be seen by reference to the columns of weights of charges in the following tables.

The hygrometric moisture in this coal, as ascertained by an experiment in the large way in the steaming apparatus, was 0.893 per cent.; and the total volatile matter derived from the two specimens above given was, for *a* 16.13, and for *b* 16.70.

The specimen *a* gave of earthy residuum 9.109, and *b* 7.398 per cent. Hence the two specimens may be considered to have the following proximate constituents, viz:

	Specimen *a*.	Specimen *b*.
Of moisture - - -	0.893	0.893
Other volatile matter - -	15.237	15.807
Earthy matter - - -	9.109	7.398
Fixed carbon - - -	74.761	75.902
	100.	100.

The volatile is here to the fixed combustible as 1 to 4.906 in the first, and 1 to 4.802 in the second specimen; and the mean is 1 to 4.854.

In the five trials of this sample under the steam boiler, there were burned 4,474.5 pounds; and the total waste withdrawn, exclusive of the ashes from wood used in heating up the boiler, was 435.75 pounds, equal to 9.739 per cent. Of this amount, 142.75 pounds, or 3.19 per cent., was clinker, and 293.04 pounds, or 6.549 per cent., ashes. Hence it appears that the clinker constitutes 32.756 per cent. of the total waste.

The ashes derived from the analyses of this coal are moderately light, and of a nearly flesh-red color.

The clinker from the furnace is much like that from Atkinson & Templeman's coal.

The same light-brown color, imperfect vitrification, and adhering white shaly masses, are here equally conspicuous as in the case just cited. The

clinker weighs 36.62, and the ashes 33.57 pounds per cubic foot. The ashes lost by reincineration 8.419, and the clinker 2.3 per cent. of weight. Hence the total absolute waste, independent of the soot, is 9.1148 per cent.

After four days' burning, there were withdrawn from the flues 12.25 pounds of soot; and subsequently, after a single day's operation, 3.5 pounds more were collected. This material weighed at the rate of 24.28 pounds per cubic foot. It appears to have produced but little effect, as the evaporation was conducted with nearly as much economy on the fourth as on the first day's experiment. The soot contained 51.41 per cent. of earthy matter.

The time required to bring the boiler to a uniform rate of action in the

First trial, was - - - - -	1.466 hour.
Second - - - - - - - -	1.666 "
Third - - - - - - - -	1.588 "
Fourth - - - - - - - -	1.500 "
Fifth - - - - - - - -	1.400 "
Mean - - - - - - -	1.523 "

The quantity of coal withdrawn from the grate, and separated, was on an average only 5.35 pounds.

The action of this sample, in all its applications, will be similar to that of the Cumberland coals above described. Deficient in volatile products for the purposes of making illuminating gas; well adapted to parlor grates, to smiths' forges where a hollow fire is not required, and to the manufacture of iron in the blast furnace, either with or without the process of coking, its high heating power will commend it for all these latter purposes; and if carefully mined, and kept free from slate and other impurities, it may sustain the character which this well-selected specimen has been enabled to establish.

A trial of heating power by the oxide of lead on 20 grains of specimen *a*, above referred to, resulted in reducing 600.2 grains of metallic lead, or 30.01 times the weight of raw coal employed. As that specimen contained 9.109 per cent. of earthy matter, the heating power of the combustible is expressed by $\frac{30.01}{.90891}=33.01$.

I have mentioned the different characters which the several columnar and amorphous plies of this coal present. In order to illustrate the respective properties of the two, I employed a specimen in which the plies of columnar coal were of rather unusual thickness, and very brilliant in the surfaces of parting. From this specimen, a portion of the columnar or crystalloid part gave of volatile matter 18.28 per cent.; earthy matter of a reddish-yellow or fawn color 1.754 per. cent.; and of fixed carbon 79.966. The volatile is, therefore, to the fixed combustible as 1 to 4.374. The coke produced by this portion was a bright intumescent porous mass.

The powder of this crystalloid coal was of a deep-brown color.

The amorphous or slaty ply of the specimen gave of a greenish-white ashes 14.736 per cent., and of volatile matter 15.976. Hence the fixed carbon is 69.288; and the volatile to the fixed combustible as 1 to 4.337.

The powder of this portion of the coal was nearly as black as the solid mass, the coke far less intumescent, and its particles less agglutinated, than those of the purer part of the lump. Twenty grains of the amorphous portion produced, when treated with oxide of lead, 25.764 times its weight of metallic lead; which, after deducting ashes, gives 30.216 times its weight of lead to 1 of combustible.

TABLE LXIX.—EASBY &

First trial—upper damper 8 inches open; air plates closed;

The period of steady action, from 8*h*. 53*m*. a. m. to 3*h*. 47*m*. p. m.—6*h*. 54*m*.; coal supplied to grate, 807.25 lbs.; water to boiler, 7,391.19 lbs., water to 1 of coal, same period, 9.156.

SMITH'S (CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet, length of circuit of heated gases 121 feet; height of chimney 63 feet.
					Water in boiler 0.5 inch below normal level; fire lighted in small furnace.
h. m.					
-	38.3	72.5	—34	-	Wind SW., brisk; clear; commenced firing at 5*h.* 26*m.*
7.25	41.7	71	+ 5	-	Wood consumed, 251½ lbs.; commenced charging with coal.
8.06	47.1	79	36	0.940	Coal ignites easily; is in good action in 6 minutes after commencing the charging.
-	44.7	85	44	1.992	
8.53	48.5	104	59	2.079	Filled tank at 9*h.* 33*m.* a. m.
9.44	47.3	116	53	3.945	Wind strong from W.; fire burning with great vigor.
10.30	48.8	125	69	2.389	
11.10	47.3	143	71	2.900	Partly filled tank.
-	48.8	151	76	4.712	Wind NW., strong; fire in vigorous action; draught high, due in part to the force of the wind.
11.57	46.5	159	70	2.834	Front valve double weighted; small weights put on back valve at 0*h.* 10*m.* p. m.; and at 0*h.* 20*m.* damper of small furnace closed, to lessen combustion.
-	50.3	169	60	2.993	
-	51.0	182	45	1.322	Combustion less active, and draught reduced.
1.04	50.3	191	44	2.612	
1.40	49.9	192.5	58	1.934	This coal does not heat the grate bars to a visible redness during its most vigorous action; filled tank at 2*h.* 10*m.* p. m.
-	47.3	196	64	2.230	
2.55	49.0	197	69	3.565	
-	47.3	202	64	2.241	
3.47	49.6	211	62	2.993	
-	50.4	207	58	2.262	Contents of ash pit thrown on grate; damper set at 4 inches; double weights removed from front valve at 4*h.* 45*m.*; water in boiler at 5*h.* 0*m.* left at 0.65 inch above normal level; at 9*h.* 0*m.* p. m. it was at 0.15 inch below normal level.
-	49.0	217	38	1.764	
-	41.7	194	14		
-	42.4	162	—24	-	Water 0.5 inch below normal level.
-	41.2	149	—22	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	42.50
Ashes - - - - - - - - - -	89.75
Ashes behind bridge - - - - - - - - -	5.36
Total clinker and ashes - - - - - - - -	107.61
Deduct wood ashes - - - - - - - - -	0.771
Total waste from coal - - - - - - - -	106.839
Coke - - - - - - - - - -	2.00

TABLE LXX.—EASBY &

Second trial—upper damper 8 inches open; air plates open;

Date.	Hour.	Temperatures of the open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Oct. 5	6.25	56	49.5	205	192	62	214	58	30.10	0.385	6.71	0.19	-	-
	7.20	54	48	172	251	62	233	57	30.12	0.565	4.93	0.29	-	104.50
	7.30	59	53	170	232	62	233	57	30.12	0.556	5.02	0.29	-	105.25
	8.30	60	54	170	273	62	232	58	30.15	0.552	5.05	0.35	330	-
	9.00	65	56	177	304	58	233	59	30.15	0.560	4.98	0.40	578	-
	9.30	66	56	181	310	58	233	61	30.15	0.560	4.98	0.40	1167	-
	10.00	67	57	185	310	58	233	63	30.16	0.555	5.02	0.38	1505	103.50
	10.30	68	58	191	303	58	232	64	30.16	0.553	5.04	0.39	1924	97.50
	11.00	70	58	196	306	58	233	65	30.16	0.551	5.06	0.40	2430	-
	11.40	71	61	208	334	58	234	67	30.16	0.560	4.98	0.40	3086	111.00
	P. M. 0.05	73	61	214	326	60	233	68	30.16	0.555	5.03	0.40	3502	-
	0.30	74	61	223	317	60	233	69	30.16	0.560	4.98	0.41	3995	96.00
	1.00	75	63	230	326	60	233	69	30.14	0.551	5.06	0.40	4582	96.00
	1.30	76	62	240	322	65	233	70	30.14	0.556	5.02	0.41	5074	-
	2.00	77	63	244	321	65	233	71	30.12	0.548	5.09	0.36	5517	104.00
	3.00	79	65	252	315	67	232	71	30.12	0.549	5.08	0.38	6451	-
	3.30	80	65	254	322	67	233	72	30.11	0.541	5.16	0.36	7166	101.25
	4.05	80	65	257	319	69	233	72	30.11	0.549	5.08	0.36	7575	98.25
	4.30	79	65	259	315	68	233	73	30.12	0.553	5.04	0.38	7825	-
	5.00	79	65	258	316	69	233	72	30.12	0.558	5.00	0.39	8240	-
	5.30	78	66	261	316	69	233	72	30.12	0.543	5.14	0.33	8780	103.25
	6.00	70	62	258	315	69	233	71	30.12	0.541	5.06	0.33	8980	-
	A. M.													
Oct. 6	4.58	52	50	196	196	68	220	58	30.05	0.426	6.29	0.22	9302	-
	5.35	58	53	196	195	68	213	57.5	30.05	0.365	6.90	0.20	9994	-

Period of steady action, from 9*h*. 44*m*. a. m. to 5*h*. 10*m*. p. m.—7*h*. 26*m*.; coal supplied to the grate, 807.25 lbs.; water to boiler, 7,094 lbs.; water to 1 of coal, same period, 8.788.

SMITH'S (CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Morning clear; wind W., light.
-	41.2	149	—22	-	Water in boiler at 0.08 inch below normal level; commenced firing; valves double weighted.
7.20	39.6	118	+18	-	Wood consumed, 102.75 lbs.
7.44	46.8	111	— 1	-	Additional weight taken from front valves at 7*h*. 34*m*. a. m.; contents of ash pit thrown on fire.
-	48.1	112	41	1.748	Filled tank at 8*h*. 32*m*. a. m.; at 8*h*. 45*m*. opened air plates.
-	48.2	112	71	1.049	Coal to be kept in a thick bed on the grate during the experiment.
-	47.3	115	87	3.121	
9.44	48.8	118	77	1.791	
10.21	50.2	123	71	2.219	
-	48.8	126	73	2.681	Additional weight removed from back valve at 11*h*. 36*m*. a. m.
11.20	54.4	137	100	2.607	Tank only partly filled, owing to the lowness of the water in the river.
-	53.1	141	93	2.644	Wind W., brisk; clear.
0.09	52.5	149	84	3.134	
1.00	55.9	155	93	3.110	At 1*h*. 17*m*. p. m., filling tank; water still very low in the river.
-	53.4	164	89	2.606	
2.00	51.8	167	88	2.347	Filled tank.
-	57.6	173	83	2.474	
3.05	57.1	174	89	3.788	Placed 28 lbs. of this coal in drying apparatus.
4.05	57.1	177	86	1.857	
-	57.6	180	82	1.589	
-	57.6	179	83	2.199	
5.10	59.8	183	83	2.596	Air plates closed.
-	56.9	188	82	1.059	Water in boiler left at 0.6 inch above normal level; damper reduced to 4 inches; 678 lbs. of water added.
-	47.5	144	—24	-	Water 1.4 inch below normal level.
-	47.8	138	—18	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	38.50
Ashes	67.75
Ashes behind bridge	5.36
Total ashes and clinker	111.61
Deduct wood ashes	0.315
Total waste from coal	111.295
Coke	5.50

TABLE LXXI.—EASBY &

Third trial—upper damper 8 *inches open; air plates closed;*

Date.	Hour.	Temperatures of the Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
Oct. 6	7.02	58.5	55	187	194	68	210	56	30.04	0.364	6.91	0.19	-	-
	7.30	56.5	53	173	249	68	217	56	30.04	0.436	6.19	0.29	-	-
	7.55	59	55.5	165	269	68	227	57	30.05	0.548	5.10	0.30	-	102.25
	8.30	62	57	173	276	68	232	58	30.05	0.543	5.14	0.34	109	-
	9.00	63	58	170	304	68	232	60	30.04	0.552	5.05	0.36	267	-
	9.30	65	59	171	294	68	230	62	30.02	0.535	5.22	0.34	674	108.50
	10.00	67	61	172	298	68	230	64	30.03	0.545	5.12	0.36	927	-
	10.30	68	61	175	310	68	231	65	30.03	0.548	5.10	0.38	1104	-
	11.10	69	62	181	298	68	231	67	30.01	0.548	5.10	0.39	1603	104.25
	P. M.													
	0.05	74	66	190	296	66	229	69	30.00	0.542	5.15	0.35	2093	-
	0.30	74	65	194	310	66	231	70	29.99	0.548	5.10	0.39	2279	103.50
	1.00	75	66	198	303	66	230	72	29.95	0.543	5.14	0.39	2697	-
	1.30	78	65.5	205	320	66	230	74	29.95	0.550	5.07	0.34	3456	99.50
	2.00	79	67	209	312	66	231	74	29.95	0.546	5.11	0.36	3619	-
	2.30	80	67	212	310	66	232	75	29.95	0.546	5.11	0.35	3927	-
	3.05	80	67	212	310	66	231	75	29.95	0.539	5.18	0.33	4337	-
	3.30	80	68	217	302	68	230	75	29.94	0.543	5.14	0.34	4663	105.50
	4.00	79	68	222	307	68	231	76	29.94	0.541	5.16	0.33	4997	-
	4.30	78	68	224	312	68	231	75	29.94	0.541	5.16	0.33	5412	96.75
	5.00	76	67	226	308	67	231	75	29.93	0.546	5.11	0.32	5734	-
	5.30	75	67	230	304	68	230	74	29.93	0.537	5.20	0.31	6141	98.50
	A. M.													
Oct. 7	4.40	67	64	204	200	68	220.5	68	29.79	0.451	6.04	0.20	6434	-
	5.25	68	65	201.5	197	68	214	68	29.78	0.386	6.69	0.19	7001	-

Period of steady action, from 9*h.* 30*m.* a. m. to 5*h.* 11*m.* p. m.=7*h.* 41*m.*; coal supplied to grate, 608 lbs.; water to boiler, 5,209.23 lbs.; water to 1 of coal, 8.567.

SMITH'S (CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 10.291 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
					Breadth of grate reduced to 2 feet 4½ inches by a row of bricks on each side.
h. m.					
-	51.7	128.5	—16	-	Water 0.12 inch below normal level; morning clear at 5h., now foggy; commenced firing at 7h. 2m. a. m.
-	49.3	116.5	+32	-	Wind WSW.; becoming clear.
8.00	52.2	106	42	-	Wood consumed, 107 lbs.; commenced charging with coal.
-	52.8	111	44	0.495	Steam blows off at 8h. 20m. a. m.
-	54.0	107	72	0.837	
9.30	54.5	106	64	2.156	The second charge of coal consists of two large lumps, and the rest fine.
-	56.9	105	68	1.340	Combustion slow.
-	52.8	107	79	0.937	Little smoke produced by this coal at chimney top, except at charging, and then only in small quantities for about 1½ minute; filled tank at 11h. 55m.
10.45	57.5	112	67	1.983	
-	61.8	116	67	1.416	
0.08	60.1	120	79	1.179	
-	61.3	123	73	2.214	
1.43	58.9	127	90	3.491	
-	61.1	130	81	0.863	From the time of the 2d charge to this hour, the rate of evaporation is 654.44 lbs. = 10.47 cubic feet per hour.
-	60.7	132	78	1.632	
-	60.7	132	79	1.862	
3.07	62.4	137	72	2.073	
-	62.8	143	76	1.769	
4.04	63.3	146	81	2.199	
-	62.5	150	77	1.706	Filled tank at 5h. 5m. p. m.
5.11	63.0	155	74	2.156	Contents of ash pit thrown on grate; damper reduced to 4 inches; water in boiler 0.6 inch above normal level.
-	62.2	137	—20.5	-	Water found 1.25 inch below normal level; raining since midnight; wind NE., light.
-	63.2	123.5	—17	-	Water adjusted in boiler; some fire still on grate at 6h. 10m. a. m.; still raining.

RESIDUA.

	Pounds.
Clinker	21.50
Ashes	56.75
Ashes from behind bridge	3.89
Total waste	82.14
Deduct wood ashes	0.328
Total waste from coal	81.812
Coke	11.75

TABLE LXXII.—EASBY &

Fourth trial—upper damper 4 inches open; air plates closed;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Oct. 7	6.45	69	66	190	194	69	212	67	29.78	0.365	6 90	0.29	-	-
	7.30	71	67	174	258.8	69	231	68	29.77	0.543	5 14	0.28	-	108.50
	8.05	70	67	172	259	70	232	68	29.77	0.523	5.34	0.32	83	107.25
	8.35	70	67	178	274	70	233	68	29.76	0.550	5.08	0.39	382	-
	9.00	73	69	182	307	70	233	69	29.75	0.542	5.15	0.37	633	-
	9.30	73	68	188	310	70	233	69	29.76	0.543	5.14	0.36	1088	-
	10.00	73	69	196	304	70	233	70	29.76	0.543	4.14	0.36	1681	107.00
	10.40	75	70	205	319	70	234	70.5	29.72	0.546	5.10	0.43	2170	104.00
	11.00	76	70	208	292	67	232	71.5	29.70	0.525	5.32	0.33	2645	-
	11.30	77	71	214	310	67	233	72	29.70	0.531	5.26	0.36	3136	101.50
	P. M. 0.00	79	72	224	301	67	232	73	29.70	0.537	5.20	0.36	3555	-
	0.30	80	73	233	326	67	234	74	29.68	0.536	5.20	0.36	3895	102.50
	1.05	81	74	243	314	67	233	75	29.67	0.535	5.22	0.36	4568	-
	1.30	83	74	246	318	67	232	76	29.67	0.530	5.26	0.35	4804	97.50
	2.00	83	74	252	314	67	232	77	29 67	0.537	5.20	0.36	4804	-
	2.30	84	75	258	314	67	232	77	29.66	0.539	5.18	0.36	4804	105.50
	3.00	84	75	262	313	69	232	78	29.66	0.543	5.14	0.38	4804	-
Oct. 8	A. M. 9.37	64	59	180	184	70	202	65	29.64	0.350	7.06	0.19	4807	-
	10.05	65	59	177	179	70	190	64	29.64	0.351	7.05	0.16	7587	-

The period of steady action this day, owing to a derangement in the feeding apparatus, extends only from 9*h*. 39*m*. a. m. to 0*h*. 29*m*. p. m.—2*h*. 50*m*. Coal supplied to the grate, 308 lbs.; water to boiler, 2,618 lbs.; water to one of coal, 8.5.

SMITH'S (CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature of the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Morning cloudy; raining since midnight; wind S., light.
-	64.3	121	—18	-	Water 0.1 inch below normal level; commenced firing at 6*h.* 45*m.* a. m.
7.30	64.9	103	+27.5	-	Wood consumed, 102.5 lbs.; commenced charging with coal; steam blows off at 7*h.* 50*m.* a. m.; manometer rose to 0.593 atmosphere before removing second weight from valve; after its removal, draught gauge rose to 0.5 inch; steam allowed to escape from back valve at 8*h.* 50*m.*
8.07	65.4	102	27	0.377	
-	65.4	108	41	1.558	
-	67.1	109	74	1.590	
-	65.5	115	77	2.411	
9.39	67.1	123	71	3.142	
10.20	67.7	130	85	1.913	
-	67.3	132	60	3.775	
11.33	68.4	137	77	2.601	
-	69.2	145	69	2.219	
0.29	70.3	158	92	1.801	
-	71.4	162	81	2.980	One of the stopcocks for the admission of water in the boiler deranged; no more water can be let in until cooled down; water 0.6 inch below normal level at 1*h.* 30*m.* p. m.
1.29	70.7	163	86	1.500	
-	70.7	169	82	-	Water in boiler 1 inch below normal level; clear, wind S., brisk.
2.10	70.4	174	82	-	Filled tank; water in boiler 3 inches below normal level.
-	70.4	178	81	-	Contents of ash pit thrown on grate at 2*h.* 45*m.*; water not visible in glass gauge; damper reduced to 3 inches.
-	55.2	116	—18	-	Found the water more than 6 inches below normal level.
-	54.5	112	—11	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	25.75
Ashes	50.75
Ashes behind bridge	3.90
Total ashes and clinker	80.40
Deduct wood ashes	0.315
Total waste from coal	80.085
Coke	4.75
Soot (4 burnings)	12.25

TABLE LXXIII.—EASBY &

Fifth trial—upper damper 8 inches open; air plates closed;

The period of steady action is from 0*h*. 25*m*. to 3*h*. 5*m*. p. m. —2*h*. 40*m*.; coal supplied to grate, 314.5 lbs.; water to boiler, 2,809.44 lbs.; water to 1 of coal, 8.911.

SMITH'S (CUMBERLAND) COAL.

steam thrown into chimney, and small furnace in action.

		grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet, length of circuit of heated gases 121 feet; height of chimney 63 feet.
					Morning cloudy; rain last night; fire kindled in small furnace.
-	44.1	95	—61	-	Water in boiler 0.65 inch below normal level; wood consumed, 159.5 lbs.
10.36	49.8	84	+ 9	-	Commenced charging with coal; water in boiler adjusted for temperature.
-	47.5	83	5	-	Steam blows off at 10*h* 45*m*.; damper set at 8 inches.
11.23	49.7	84	33	1.426	Coal on grate in general ignition at 11*h*. 23*m*. a. m.
-	51.0	91	48	2.638	Steam allowed to escape from back valve.
0.25	53.4	94	48	2.978	Fire in good action; commenced drawing gases at 0*h*. 34*m*. p. m.; drew in 46 minutes 100 cubic inches, which gave water 0.72 grain, carbonic acid 9.07 grains, and oxygen 10 cubic inches.
-	53.6	101	49	2.826	
1.15	56.7	110	64	2.103	
-	55.8	123	53	3.116	
2.15	55.2	130	62	3.799	Wind SW., brisk.
-	56.4	141	76	-	Filled tank.
3.05	67.1	146	67	2.583	Contents of ash pit thrown on grate.
-	55.2	150	39	2.172	Damper reduced to 4 inches at 3*h*. 45*m*. p. m.
-	58.6	165	23	0.858	
-	53.0	168.5	12	0.889	Small weights placed on safety valve; water in boiler 0.25 inch above normal level.
-	52.2	154	—26	-	Water in boiler adjusted to the proper level; and, as the pressure does not rise when the valves are double weighted, the experiment is closed.
-	51.9	112	—29		

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	14.50
Ashes (including those behind bridge) - - - - - - -	41.75
Total clinker and ashes - - - - - - - - -	56.25
Deduct wood ashes - - - - - - - - -	0.49
Total waste from coal . - - - - - - - -	55.76
Coke - - - - - - - - - - - -	1.75
Soot from this day's burning - - - - - - - -	3.60

TABLE LXXIV.—DEDUCTIONS FROM

Experiments on Easby &

	Nature of the data furnished by the respective tables.	1st trial. (*Table LXIX.*)	2d Trial. (*Table LXX.*)
		October 4.	*October* 5.
1	Total duration of the experiment, in hours - -	24.583	23.167
2	Duration of steady action, in hours - - -	6.9	7.433
3	Area of grate, in square feet - - - - -	14.07	14.07
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18 75
6	Number of charges of coal supplied to grate - -	11.0	11.0
7	Total weight of coal supplied to grate, in pounds -	1105.0	1120.5
8	Pounds of coal actually consumed - - -	1102.0	1115.0
9	Pounds of coal withdrawn and separated after trial -	3.0	5.5
10	Mean weight, in pounds, of one cubic foot of coal -	50.227	50.931
11	Pounds of coal supplied per hour, during steady action -	116.993	108.603
12	Pounds of coal per square foot of grate surface, per hour	8.314	7.718
13	Total waste, ashes and clinker, from 100 pounds of coal	9.695	9.982
14	Pounds of clinker alone, from 100 pounds of coal -	3.8286	3.4422
15	Ratio of clinker to the total waste, per cent. - -	39.492	34.485
16	Total pounds of water supplied to the boiler - -	9738.0	9971.0
17	Mean temperature of water, in degrees Fahrenheit -	62°.5	63°.2
18	Pounds of water supplied at the end of experiment, to restore level - - - - - - -	188.0	669.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds - - - -	27.0	100.0
20	Pounds of water evap. per hour, during steady action -	1071.18	954.39
21	Cubic feet of water per hour, during steady action -	17.138	15.27
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - -	2.837	2.528
23	Pounds of water per square foot, by a mean of several observations - - - - - -	2.821	2.509
24	Water evap. by 1 of coal, from initial temp. (a) final result	8.803	8.8529
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action - - - -	9.156	8.788
26	Pounds of fuel evaporating one cubic foot of water -	7.0998	7.0598
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - -	69°.03	72°.3
28	Mean temp. of wet bulb thermom., during steady pressure	57°.5	60°.8
29	Mean temperature of air, on arriving at the grate -	231°.61	221°.5
30	Mean temperature of gases, when arriving at the chimney	291°.39	310°.1
31	Mean temperature of steam in the boiler - -	233°.61	232°.9
32	Mean temperature of attached thermometer - -	65°.56	67°.2
33	Mean height of barometer, in inches - - -	29.924	30.1375
34	Mean number of volumes of air in manometer - -	4 846	5 0435
35	Mean height of mercury in manometer, in atmospheres -	0.5727	0.5525
36	Mean height of water in syphon draught gauge, in inches	0.3066	0.3825
37	Mean temperature of dew point, by calculation - -	48°.5	58°.3
38	Mean gain of temp. by the air, before reaching grate -	162°.58	149°.2
39	Mean difference between steam and escaping gases -	61°.47	85°.5
40	Water to 1 of coal, corrected for temp. of water in cistern	8.803	8.8529
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - -	10 085	10.1336
42	Pounds of water, from 212°, to one cubic foot of coal -	506.54	516.11
43	Water, from 212°, to 1 pound of combustible matter of the fuel - - - - - - -	11.1676	11.2573
44	Mean pressure, in atmospheres, above a vacuum -	1.4958	1.4425
45	Mean pressure, in pounds per sq. inch, above atmosphere	7.3222	6 5352
46	Condition of the air plates at the furnace bridge -	Closed.	Open.
47	Inches opening of damper, (U. upper) - -	U. 8	U. 8

TABLES LXIX, LXX, LXXI, LXXII, LXXIII.

Smith's coal, (Cumberland.)

3d Trial. (*Table LXXI.*)	4th Trial. (*Table LXXII.*)	5th Trial. (*Table LXXIII.*)	Averages.	Remarks.
October 6.	*October 7.*	*November 16.*		
22.333	27.333	10.667		
7 683	4.517	2.667		
10.291	14.07	14.07	–	It will be remarked that the size of the grate in the 3d trial was much less than in either of the others—reduced by rows of bricks on the sides. No advantage appears to have attended this alteration, as will be seen by consulting the deductions below; lines 40, 41, 42, and 43.
377.5	377.5	377.5		
18.75	18.75	18.75		
8 0	8.0	6.0		
818.75	833.75	624.25		
807.0	829.0	622.5		
11.75	4.75	1.75	5.35	
51.1718	52.109	52.0208	51.2919	
79 135	113.135	117.592	107.092	
7.689	8.041	8.351	8.0228	
10.137	9.6605	8.9575	9.6864	
2.6543	2.9928	2.3097	3.0455	
26.183	30.979	25.7855	31.3849	
7001.0	7587.0	5320.0		
67°.0	67°.6	46°.0		
567.0	2780.0	0.0	–	The 5th experiment was brought entirely to a close, and the water level adjusted, before leaving the apparatus, on the day of trial.
78.0	363.0	0.0		
678.02	924.11	1051.544	935.849	
10.848	14.785	16.825	14.973	
1.796	2.448	2.786	2.479	
1.788	2 467	2.725		
8.5785	8.7141	8.546	8.6989	
8.567	8.5	8.911	8.7844	
7.2856	7.1724	7.3134	7.1862	
73°.44	77°.93	60°.4		
61°.42	71°.5	56°.7		
198°.94	220°.64	170°.7	208°.68	
304°.11	308°.29	282°.9	299°.36	
230°.72	232°.71	232°.4		
70° 0	72°.86	56°.8		
29.98	29.704	30.132		
5.1311	5.185	4.987		
0.5441	0.5383	0.5579		
0.3520	0.3664	0.35	0.3677	
59°.26	68°.69	58°.54		
125°.5	142°.71	110°.3	138°.06	
75°.19	78°.46	59°.5	72°.02	
8.5631	8 6971	8.546	8.6924	
9.7686	9.9164	9.8283	9.8654	
499.88	516.73	516.22	511.096	
10.8705	10.977	10.8997	11.0344	The open air plate appears to have produced some advantage in the 2d trial of this sample.
1.4328	1.4123	1.441	1.4449	
6.3917	6.089	6.5126	6.5701	
Closed.	Closed.	Closed.		
U. 8	U. 4	U. 8		

No. 6.

Bituminous coal from Cumberland, procured for use in the navy yard.

This is the same sample of Cumberland coal from which were taken the four charges used in making mixtures with Beaver Meadow anthracite, as already detailed.

The only separate experiment made with this coal was in one of the preliminary trials of the apparatus. In that trial, the coal was used in heating up the boiler, as well as in generating steam. No decisive result could be, with confidence, deduced from that trial; and I therefore abstain from any other than a general exhibition (in the synoptical table which follows this class of coals) of such points as were determined by analysis, and such as an examination of the residua of the combustion enables me to offer. It will not fail to be observed, that the total *waste* from this sample was more than that from any of the samples *sent for trial* from the Cumberland region. The five samples thus sent gave an average of 9.939 per cent. of waste, including clinker and ashes; while the coal furnished to the yard gave 14.526 per cent. A similar, or greater, difference will be hereafter observed between the impurity of a sample of Midlothian coal purchased for use in the yard, and all the samples of the same coal sent by the company for these trials. This observation points to the necessity of greater vigilance in mining, and more caution in purchasing coal.

No. 7.

Bituminous coal from the Dauphin and Susquehanna Coal Company of Pennsylvania, sent by Isaac Lea, Esq., of Philadelphia.

The following statement, relative to the origin of this sample, is contained in a letter received by the undersigned, and dated

"PHILADELPHIA, *August* 18, 1842.

"DEAR SIR: I have just heard of the shipment from Dauphin of three hogsheads and one barrel of the 'Dauphin or Stony Creek coal.' It goes to the care of Mr. N. Hickman, Baltimore, with directions to forward it to Commodore Kennon, as you requested.

"I ordered it to be taken out of 'Perseverance vein,' wishing to send you fresh coal; but have some fears that it may not have been as well mined, or as well selected, as it ought to have been, as there was no regular miner on the spot.

"I beg that you will make all allowance for any defect that may arise from the circumstances—preferring to have no report rather than one which might deteriorate from the character already established.

"You have my best wishes for a satisfactory termination of your present arduous duty.

"Very respectfully,

"ISAAC LEA.

"Professor WALTER R. JOHNSON."

In a verbal statement afterwards made, Mr. Lea mentioned that his fears above referred to, in regard to the selection of the sample, were subsequently ascertained to be in a measure justified; and that a part of it, instead of being freshly mined, had in fact been taken from a heap which had been for two or three years lying near the mouth of the pit.

The exterior aspect of this coal is more anthracitious than bituminous. Fractures frequently follow the surfaces of deposition; striated and very smooth faces oblique to those surfaces not unfrequently occur. A set of shining faces, forming the main partings, appear to observe the general inclination of 80° and 100° to the surfaces of deposition. Alternating plies of bright and dull black present themselves conspicuously in the directions of the cross-partings, but they are less strongly marked than in the Cumberland coals.

The specific gravity of one specimen of this sample was found to be 1.6209, and of another 1.4431. The mean of these gives the calculated weight per cubic foot 97.5 pounds; whereas twenty-six trials in the charge box gave a mean of 50.538, varying from 46 to 55 pounds as the extremes, or 0.5184 of the calculated weight. The space required to stow one ton is 44.323 cubic feet.

The analysis of the two specimens of this coal, of which the specific gravity has been given, showed the first to contain 0.582, and the second 0.646 per cent. of moisture.

In the steam drying apparatus, 28 pounds lost in three days only 2 ounces, or 0.4464 per cent.

The volatile ingredients, other than water, in the first specimen were 14.148, and in the second 12.776. The coking gives a considerable increase of bulk, and the coke is tough and coherent. The gas burns with a bright yellow flame.

On two other specimens of this sample, four experiments were made by Dr. King, which afforded a mean of 14.562 per cent. of volatile matter; and the mean of the six, including the two on my own specimens, is 14.292. Besides these trials, made expressly to determine the proportion of volatile matter, and performed in close vessels, a set of four trials was made while performing the incineration of the first specimen, of which the result was 14.67 per cent.

The four experiments just referred to proved the earthy matter of the first specimen to be 17.94; and eight others, on the second specimen, gave 21.09 per cent. of the same materials. The ashes are bulky, slightly gritty, and of a bright fawn color.

The presence of a considerable portion of oxide of iron is indicated by the color of these ashes, and becomes further apparent during the combustion on the grate.

In three trials under the boiler, there were consumed of this coal 2,557.5 pounds, leaving of clinker 91.5, and of ashes 323.65 pounds: whence it appears that the former was 3.578, and the latter 12.658 per cent. of the coal burned; or the *total waste* drawn from the furnace was 16.236 per cent.

By reincinerating, the ashes lost 37.76 per cent. of their weight, and the clinker 1.69 per cent.; so that the amount of waste from the furnace was 11.396 per cent., and from the flues an addition (as seen below) of 0.098—making the whole 11.494 per cent. of matter actually incombustible.

The proportion of sulphur in specimen *a*, ascertained in the manner already described, was 0.269 per cent. Hence, admitting the volatile matter to have been correctly ascertained by the above experiments, we obtain for the composition of the Dauphin coal—

Water, as proved in the large apparatus - -	0.446 per cent.
Sulphur, by trial on one specimen - - -	0.269 "
Volatile matter, other than above (by six trials) -	13.577 "
Earthy matter, from the furnace operations - -	11.494 "
Carbon, not volatilizable by heat alone - - -	74.214 "
	100.

The clinker weighs 32.25 pounds per cubic foot; is chiefly of a reddish-brown color, with some yellowish-white portions; is porous, and often has large adhering fragments of slaty matter, but little vitrified.

The ashes weigh 44.62 pounds per cubic foot, have a slight tinge of redness, and, when reduced to powder, become almost perfectly black, from the unburnt coal which they contain.

After three days' burning, the flues afforded 5¾ pounds of soot and dust, weighing at the rate of 12.45 pounds per cubic foot; which obviously had but little effect in impeding the passage of heat into the boiler, since the efficiency of the pound of fuel was higher on the second day than it had been on the first; and the gas entered the chimney at a lower temperature on the third day than on either of the preceding.

This coal takes fire promptly. The time elapsed between the commencement of charging with coal, and the establishment of the rate of steady action, was on the first trial 0.75 hour, on the second 0.66, and on the third 1.08; or, on an average, about 0.83 hour, or 50 minutes. The average weight of unburnt coke left on the grate after each trial was 23.67 pounds.

In the smith's fire, the coal worked moderately well, but presented the objectionable feature of giving a large amount of cinder. Sixty pounds were found sufficient to make nine links of a chain 1⅝ inch in diameter.

The sample was too small to afford an opportunity of making all the trials which might have been desirable. No trial is recorded as having been made in the office grate; but, from the characters it exhibited in the furnace, no reasonable doubt can be entertained of its proving satisfactory for domestic purposes.

A single trial of heating power by the oxide of lead on specimen *a* yielded 25.325 times its weight of metallic lead. Deducting 18.525 per cent., the sum of its earthy matter and moisture, this gives to 1 of combustible a reductive power of 31.083.

The following tables exhibit the mode of action of this coal under the boiler; and the subsequent table of deductions exhibits all the important conclusions to which they lead.

This sample of coal is interesting, as illustrating the passage of the anthracite beds of Pennsylvania, near their southwestern termination, into those of a decidedly bituminous character. In undergoing the process of coking, the masses became slightly agglutinated together, still retaining, to some degree, the original forms. The coke is tough, and has a brilliant plumbaginous lustre.

NOTE.—Under date of May 22, 1844, Mr. Lea gave the following information:

"DEAR SIR: I hear to-day, from the person who procured the coal sent to you from Perseverance vein, in the Dauphin Coal Company's lands, that there was not a single pound of it mined for the purpose of sending to you, agreeably to my orders; but that the whole of it was raked out of a heap of rubbish which had been lying at the mouth of the drift *for three years*, exposed to the ice of winter and heat of summer; and, of course, deteriorated. I expressly ordered it be mined fresh for the trial; but I am told to-day that 'there was not a pick put *into the vein for the purpose*.'

"I am, very respectfully, your obedient servant,

"ISAAC LEA.

"Professor W. R. JOHNSON."

TABLE LXXV.—DAUPHIN AND SUSQUE

First trial—upper damper 8 *inches open ; air plates closed ;*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
July 27	4.25	80	72	142	174	80	182	79	30.10	0.350	7.06	0.10	-	-
	6.30	80	72	140	246	80	227	80	30.09	0.527	5.30	0.20	-	92.00
	6.45	80.5	72.5	146	256	80	232	80	30.09	0.541	5.16	0.30	-	95.75
	7.00	81	73	149	268	80	232	81	30.09	0.550	5.08	0.32	237	-
	7.15	81	73	154	280	80	232	81.5	30.10	0.543	5.14	0.30	490	-
	7.30	82	73	160	284	80	232	81	30.09	0.551	5.06	0.30	797	98.75
	8.00	83	74	173	296	81	234	82	30.09	0.545	5.12	0.30	1360	95.50
	8.30	86	76	190	298	80	233	83	30.09	0.541	5.16	0.30	1998	102.00
	8.50	89	77	202	310	80	232	84	30.12	0.538	5.19	0.30	2574	-
	9.30	91	77	225	288	80	232	86	30.12	0.520	5.37	0.25	3234	-
	10.00	93	77	236	287	80	232	87	30.12	0.529	5.28	0.27	3607	-
	10.30	94	78	246	288	80	232	88	30.12	0.539	5.18	0.28	4029	96.00
	11.00	95	78	250	290	80	232	89	30.12	0.529	5.28	0.27	4540	-
	11.30	95	78	256	282	80	232	90	30.12	0.525	5.32	0.27	4890	106.50
	P. M.													
	0.00	98	80	262	274	80	232	90	30.12	0.524	5.33	0.26	5199	-
	0.30	98	79	264	264	80	231	91.5	30.12	0.528	5.29	0.28	5544	106.25
	1.00	98	81	268	268	80	232	92	30.12	0.528	5.29	0.30	6055	105.25
	1.30	99	80	270	269	81	232	92.5	30.12	0.533	5.23	0.30	6496	-
	2.00	100	80	274	274	82	231	93	30.12	0.529	5.28	0.29	6854	-
	2.30	100	80	278	274	82	232	94	30.09	0.523	5.34	0.28	7299	107.75
	3.30	102	82	286	260	87	230	94	30.08	0.495	5.60	0.22	7787	-
	4.30	100	80	284	238	87	229	94	30.07	0.496	5.59	0.20	8029	-
	A. M.													
July 28	5.00	76	74	200	198	88	218	81	30.06	0.379	6.76	0.10	8029	-
	5.15	77	72	199	196	88	217	81	30.06	0.369	6.86	0.10	8189	-

Period of steady action, from 7*h*. 35*m*. a. m. to 2*h*. 30*m*. p. m.=6*h*. 55*m*.; coal supplied to grate, 719.25 lbs.; water to boiler, same time, 6,408 lbs.; water to 1 of coal, 8.909.

HANNA COMPANY'S (BITUMINOUS) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	68.8	62	— 8	-	Commenced firing; water 0.25 inch below normal level;
6.30	68.8	60	+19		morning clear; wind SW., light; wood consumed, 202 lbs.; commenced charging with coal; it ignites promptly.
6.45	69.4	65.5	24	-	Steam blows off at 6h. 45m. a. m.
-	70.0	68	36	2.511	Fire very active; coal burns with a clear yellow flame;
-	70.0	73	48	2.681	swells and cracks in coking, but does not either agglu-
7.35	69.6	78	52	3.253	tinate or fall into "slack;" very free burning; weight on the valves equalized.
8.10	70.7	90	62	2.983	
8.30	72.7	104	65	3.380	Grate rather overcharged; too much action excited; smoke at chimney top.
-	73.2	113	78	4.577	Filled tank partly at 9h. 20m. a. m.
-	72.7	134	56	2.622	Coal in grate reduced; proper action re-established.
-	72.1	148	55	1.976	Filled tank at 9h. 50m. a. m.
10.10	73.3	152	56	2.235	Wind NW., light; day somewhat obscured by light clouds.
-	73.0	155	58	2.707	
11.10	73.0	161	50	1.854	
-	75.2	164	42	1.687	Smoke 15 seconds in reaching chimney top; lower damper open 8 inches; syphon 0.24, with upper damper 8 inches 29 seconds; commenced drawing gases from lower open-
0.20	73.7	166	33	1.828	ing at 0h. 35m. p. m.; drew in 30 minutes 100 cubic
1.00	76.6	170	36	2.707	inches, which gave water 1.22 grain, carbonic acid 4.76
-	73.5	171	37	2.386	grains, oxygen 13.22 cubic inches.
-	74.7	174	43	1.896	Dew point, by observation, 78°.
2.30	74.7	178	42	2.357	Wind NW., clear; cloudy around the horizon.
-	77.0	184	30	1.292	Filled tank at 3h. 15m. p. m.; contents of ash pit put on grate; damper reduced to 5 inches.
-	74.7	184	9	-	Water at 0.5 inch above normal level; filled tank at 4h. 45m. p. m.
-	73.2	124	—20		
-	69.9	122	—21	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	39.25
Ashes	111.50
Ashes behind bridge	1.55
Total waste	152.30
Deduct wood ashes	0.62
Total waste from coal	151.68
Coke	17.50

TABLE LXXVI.—DAUPHIN AND SUSQUE

Second trial—upper damper 8 inches open; air plates open;

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
July 28	5.15	77	72	199	196	88	217	81	30.06	0.369	6.86	0.10	-	-
	6.20	84	77	187	230	88	228	81	30.06	0.523	5.34	0.17	-	106.25
	6.30	83	77	188	260	88	232	81.5	30.06	0.543	5.14	0.24	-	93.50
	7.00	84	77	187	296	87	232	82	30.07	0.541	5.16	0.27	546	-
	7.30	85	77.5	193	300	87	231	83	30.07	0.543	5.14	0.32	886	-
	8.00	86	77	202	310	87	232	84	30.07	0.541	5.16	0.31	1505	98.75
	8.30	88	78	210	306	87	232	86	30.06	0.530	5.27	0.28	2020	-
	9.00	95	82	222	300	87	232	86	30.06	0.527	5.30	0.26	2450	95.50
	9.30	92	79	231	302	87	232	88	30.06	0.522	5.35	0.28	2875	-
	10.00	94	79	236	298	87	232	89	30.06	0.531	5.26	0.28	3248	100.00
	10.30	96	80	244	290	87	232	90	30.05	0.531	5.26	0.28	3642	-
	11.05	98	80	248	294	88	232	92	30.05	0.529	5.28	0.28	4080	102.50
	11.20	99	80	250	305	88	232	92	30.06	0.534	5.23	0.31	4335	-
	P. M. 0.10	100	79	256	300	86	232	93	30.05	0.533	5.24	0.31	4930	102.75
	0.40	101	80	250	-	86	232	94	30.04	0.549	5.10	0.38	5440	-
	1.15	102	80	250	300	86	232	94	30.03	0.521	5.36	0.29	6020	104.75
	1.45	102	78	260	300	86	232	95	30.025	0.530	5.27	0.34	6412	-
	2.15	102	78	266	302	86	232	95	30.02	0.525	5.32	0.30	6842	100.75
	2.45	102	79	270	280	86	232	95	30.00	0.515	5.42	0.28	7185	-
	4.00	102	78	276	240	86	226	95.5	29.97	0.492	5.64	0.22	7450	-
July 29	A. M. 4.15	86	75	218	205	86	220	86	29.93	0.400	6.56	0.10	7460	-
	4.55	88.5	77.5	213	205	86	218	84	29.92	0.373	6.83	0.10	7690	-

Period of steady action, from 7*h.* 45*m.* a. m. to 2*h.* 15*m.* p. m.—6*h.* 30*m.*; coal supplied to grate, same time, 606.25 lbs.; water to boiler, 5,337 lbs.; water to 1 of coal, 8.803.

HANNA COMPANY'S (BITUMINOUS) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	69.9	122	—21	-	Water in boiler 0.09 inch above normal level at 214°; commenced firing.
6.20	74.7	103	+ 2	-	Wood consumed, 85 lbs.; commenced charging with coal; morning clear; wind SW., light.
6.30	75.0	105	28	-	Fire already in good action; steam blows off; air plates opened.
-	74.7	103	64	2.892	No smoke perceptible at chimney top.
-	75.2	108	68	1.801	
7.45	74.1	116	78	3.279	
....			....	....	
-	74.9	122	74	2.728	
8.55	78.7	127	68	2.278	The observation in dry and wet bulb thermometer, at this set, is probably incorrect, from some transient cause, as
-	75.2	139	70	2.251	in a few minutes after they were 92°, 79°=dew point,
10.00	74.7	144	66	1.976	75°.2.
-	75.7	148	58	2.087	A light brown smoke, lasting 2 or 3 minutes, at chimney top after charging.
11.05	75.2	150	62	1.988	Dew point, by observation, 73°.
-	75.0	151	73	2.702	Wind SW., brisk; clear; clouds around the horizon; filled tank at 11h. 53m.
0.10	73.2	156	68	1.896	Commenced drawing gases from lower flue at 0h. 12m.;
-	74.0	149	-	2.702	drew in 56 minutes 80 cubic inches, which gave water
1.10	74.7	148	68	2.633	1.04 grain, carbonic acid 4.21 grains, oxygen 11.11
-	71.3	158	68	2.076	cubic inches.
2.15	71.3	164	70	2.278	
....	....	....	....	....	
-	72.0	168	48	1.817	Air plates closed; contents of ash pit thrown on grate; damper set at 4 inches.
-	71.3	174	12	-	Water left at 0.4 inch above normal level.
-	71.2	132	—15	-	Water in boiler 0.3 inch below normal level.
-	74.0	124.5	—13	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	32.50
Ashes - - - - - - - - - - -	110.50
Ashes from behind bridge - - - - - - - -	1.38
	144.38
Deduct wood ashes - - - - - - - - -	0.247
Total waste from coal - - - - - - - - -	144.133
Coke - - - - - - - - - - -	19.25

TABLE LXXVII.—DAUPHIN AND SUSQUE

Third trial—upper damper 4 inches open; air

Date.	Hour.	Temperatures of the							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m.													
	A. M.													
July 29	5.20	85	76	204	202	86	215	83	29.90	0.370	6 85	0.12	-	-
	5.55	90	78	194	260	86	227	83	29.90	0.527	5.30	0.25	-	100.25
	6.30	88	77	190	268	86	230	85	29.92	0.541	5.16	0.27	-	-
	7.00	86.5	76.5	196	260	86	230	86	29.93	0.530	5.27	0 20	405	101.25
	7.30	88	77	210	263	82	231	86.5	29.93	0.524	5.33	0.20	790	-
	8.00	90	78	223	262	82	231	87	29.92	0 524	5.33	0.20	1125	110.00
	8.30	94	80	236	262	82	230	88	29 93	0.524	5.33	0 20	1510	-
	9.00	95	80	251	260	82	232	90	29.93	0.532	5.25	0.20	1852	-
	9.30	96	80	258	258	82	231	91	29.93	0.531	5.26	0.20	2192	98 50
	10.00	99	82	265	268	82	232	92	29.93	0.526	5.31	0.20	2580	-
	10.30	99	81	274	258	82	232	93	29.95	0.525	5 32	0.20	3010	103.50
	11.00	100	82	279	258	82	231	93	29.94	0.525	5.32	0.20	3364	-
	11.30	101	82	283	264	82	232	94	29.96	0.527	5.30	0.20	3663	103.75
	P. M.													
	0.00	102	82	289	257	83	232	94	29.94	0.530	5.27	0.20	3984	-
	0.30	102	82	286	-	83	231	94.5	29 94	0.540	5.17	0.21	4320	-
	1.00	101	82	291	264	84	232	95	29.95	0.513	5.44	0.20	4852	100.25
	1.35	101	80	288	254	87	230	95	29.93	0.510	5.47	0.22	-	-
	2.00	102	80	286	250	87	229	95	29.92	0.500	5.56	0.20	5179	-
	3.55	99	80	283	228	87	228	94	29.91	0.489	5.66	0.10	5336	-
	A. M.													
July 30	6.15	86	77	214	190	87	216	86	29.94	0.368	6.88	0.13	5341	-
	6.45	86	77.5	206	200	87	214	86	29.93	0.347	7.09	0.13	5564	-

The period of steady action, from 7*h*. a. m. to 0*h*. 45*m*. p. m. = 5*h*. 45*m*. Coal supplied to grate, 516 lbs.; water to boiler, 4,181 lbs.; water to 1 of coal, 8.103.

HANNA COMPANY'S (BITUMINOUS) COAL.

plates closed; steam thrown out at back valve.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	73.0	119	— 13	-	Commenced firing; water 0.15 inch above normal level.
5.55	74.4	104	+ 33	-	Wood consumed, 72.5 lbs.; morning clear; wind NW., light; commenced charging with coal.
-	73.5	102	38	-	Steam blows off; damper set to 4 inches.
7.00	73.2	109.5	30	2.145	Filled tank at 7*h*. 7*m*.
-	73.5	122	32	2 039	Fire in small furnace extinguished.
8.06	74.4	133	31	1.774	
-	76 1	142	32	2 039	
-	75.9	156	28	1.812	Fire in steady moderate action.
9.15	75.7	162	27	1.801	
-	77.8	166	36	2 055	
10.25	76.4	175	26	2.278	
-	77.5	179	27	1.822	Dew point in free air, by observation, 73°.5.
11.30	77.2	182	32	1.637	
-	77.1	187	27	1.700	28 lbs. of this coal, after being dried in apparatus, weighed 27 lbs. 14 oz.
-	77.1	184	-	1.780	Commenced drawing gas from lower flue at 0*h*. 18*m*.; drew 80 cubic inches in 21 minutes, which gave water 0.9 grain,
0.45	76.1	190	32	2 818	carbonic acid 4.17 grains, oxygen 9.074 cubic inches; temperature at bath 95°.
-	74.5	187	24	-	Filled tank.
-	74.2	184	21	0.866	Contents of ash pit thrown on grate.
-	75.0	184	0	-	Damper closed, and air port stopped.
-	74.1	128	— 26	-	Water 0.35 inch below normal level.
-	74.8	120	— 14	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	19.75
Ashes	98.75
Ashes behind bridge	1.07
Total clinker and ashes	119.57
Deduct wood ashes	0.223
Total waste from coal	119.347
Coke	34.25
Soot	5.75

TABLE LXXVIII.—DEDUCTIONS

Experiments on Dauphin and

	Nature of the data furnished by the respective tables.	1st Trial. (*Tab. LXXV.*)	2d Trial. (*Tab. LXXVI.*)
		July 27.	*July* 28.
1	Total duration of the experiment, in hours	24.833	23.667
2	Duration of steady action, in hours	6.917	6.50
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	10.0	9.0
7	Total weight of coal supplied to grate, in pounds	1005.75	904.75
8	Pounds of coal actually consumed	988.25	885.5
9	Pounds of coal withdrawn and separated after trial	17.50	19.25
10	Mean weight, in pounds, of one cubic foot of coal	50.2875	50.322
11	Pounds of coal supplied per hour, during steady action	103.99	97.0
12	Pounds of coal per square foot of grate surface, per hour	7.319	6.894
13	Total waste, ashes and clinker, from 100 pounds of coal	15.348	16.275
14	Pounds of clinker alone, from 100 pounds of coal	3.9565	3.6635
15	Ratio of clinker to the total waste, per cent.	25.778	22.509
16	Total pounds of water supplied to the boiler	8189.0	7690.0
17	Mean temperature of water, in degrees Fahrenheit	80°.9	86°.5
18	Pounds of water supplied at the end of experiment, to restore level	160.0	230.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	20.0	28.0
20	Pounds of water evaporated per hour, during steady action	926.54	853.9
21	Cubic feet of water per hour, during steady action	14.824	13.60
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.454	2.262
23	Pounds of water per square foot, by a mean of several observations	2.506	2.299
24	Water evaporated by 1 of coal, from initial temperature, (a) final result	8.267	8.653
25	Water evaporated by 1 of coal, from initial temperature, (b) during steady action	8.909	8.803
26	Pounds of fuel evaporating one cubic foot of water	7.5602	7.223
27	Mean temperature of air entering below ash pit, during steady pressure	91°.31	94°.19
28	Mean temp. of wet bulb thermom., during steady pressure	77°.09	78°.84
29	Mean temperature of air, on arriving at the grate	222°.39	230°.94
30	Mean temperature of gases, when arriving at the chimney	280°.56	297°.53
31	Mean temperature of steam in the boiler	232°.06	232°.0
32	Mean temperature of attached thermometer	86°.97	89°.03
33	Mean height of barometer, in inches	30.109	30.052
34	Mean number of volumes of air in manometer	5.233	5.240
35	Mean height of mercury in manometer, in atmospheres	0.5342	0.5331
36	Mean height of water in syphon draught gauge, in inches	0.2821	0.2992
37	Mean temperature of dew point, by calculation	72°.67	74°.56
38	Mean gain of temperature by the air before reaching grate	131°.08	136°.75
39	Mean difference between steam and escaping gases	50°.928	67°.73
40	Water to 1 of coal, corrected for temp. of water in cistern	8.2353	8.6154
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.2835	9.6652
42	Pounds of water, from 212°, to 1 cubic foot of coal	466.84	486.37
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	10.967	11.544
44	Mean pressure, in atmospheres, above a vacuum	1.4234	1.4271
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.2533	6.3077
46	Condition of the air plates at the furnace bridge	Closed.	Open.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

FROM TABLES LXXV, LXXVI, LXXVII.

Susquehanna Company's coal.

3d Trial. (*Tab. LXXVII.*)	Averages.	Remarks.
July 29.		
25.417		
5.75		
14.07		
377.5		
18 75		
·7.0		
717.5		
683.25		
34.25	23.67	The slow combustion in the 3d trial, carried on with a damper drawn but four inches, appears in this, as in many other instances, to have caused the early extinction of the fire, leaving nearly double as much unburnt coke on the grate as in either of the other two experiments.
51.25	50.6198	
89.722	96.904	
6.377	6.863	
17.467	16.363	
2.8653	3.5018	
16.518	21.602	
5564.0		
83°.0		
228.0		
28.0		
727.131	835.857	
11.634	13.353	
1.926	2.214	
1.887		
8.1024	8.3408	
8.103	8.605	More coal appears to have been burned during the period of steady action, in the 1st and 2d trials, than was actually put upon the grate in the same time. This is easily accounted for, by the fact that the large amount of waste left on the grate augmented the apparent bulk of the fuel at the end of that time.
7.7138	7.499	
96°.38		
80°.35		
257°.0	236°.78	
261°.17	279°.75	
231°.31		
91°.08		
29.936		
5.300		
0.527		
0.2009	0.2607	
76°.0		
160°.62	142°.82	
29°.8	49°.486	
8.0692	8.3066	
9.0798	9.2428	
465.34	472.85	
11.0014	11.1708	The *combustible matter* of this coal has a very high evaporative power, though the large proportion of *waste*, as seen in line 13, detracts considerably from its efficiency as a fuel.
1.4143	1.4216	
6.1184	6.2265	
Closed.		
U. 4		

No. 8.

Bituminous coal from Blossburg, Tioga county, Pa., sent by the Arbon Coal Company.

The following letter contains the information required by the department to accompany each sample of coal furnished for trial in these experiments:

"BLOSSBURG, *June* 24, 1842.

"*To the Board of Commissioners of the Navy Department:*

"GENTLEMEN: In accordance with an advertisement published by the department in the Commercial Advertiser, New York, of April 14, 1842, calling upon proprietors of mines, and others furnishing fuel, to forward a quantity of the fuel they respectively furnish to Washington, for trial, the Arbon Coal Company have despatched to the navy yard at Washington two tons of the coal worked at their mines, for the above specified objects. This coal was worked in the month of January, at the mines belonging to the company, and situated in Blossburg, Tioga county, Pennsylvania, and has been lying exposed to the weather till packed for exportation, May 12, 1842. It forms a fair sample of the quality of the coal constituting the vein they now work. It is, on an average, three feet in thickness, pure, and of very superior quality. It is mined and filled into the railroad cars directly at the openings, is sent to Corning, and there tipped into the canal boats, which proceed through the Chemung canal to the New York and Erie, and so on to Albany and New York, where it would be most convenient to deliver any quantities that may be contracted for.

"I take pleasure in signing myself your very obedient servant,

"J. W. JOHNSTON,

"*Superintendent of Arbon Coal Company.*"

The exterior characters of this coal are a columnar structure, with the main partings inclined to the surfaces of deposition, in angles varying from 80 to 85 degrees. The color is a deep shining black, with but few plies of a dull aspect. The horizontal partings are in some instances marked with efflorescent sulphate of iron, the presence of which is easily recognised by the senses. This efflorescence of the sulphuret into the sulphate appears to be the chief cause of the disintegration, more or less rapid, of the different coals in which it takes place.

The specific gravity of one specimen examined was found to be 1.3236, and that of another 1.9542. The latter doubtless contained an undue proportion of sulphuret of iron. Admitting the first to be a fair average result, the weight of a cubic foot will be 82.73 pounds. The weight in its merchantable state, as determined by 41 trials in the charge box, was from 49.625 to 57.25 pounds, and on an average 53.048 pounds per cubic foot. It follows that the space required for stowing one ton will be 42.221 cubic feet.

The moisture expelled from specimen *a* was 0.758, and that from *b* 0.683 per cent.

From 28 pounds dried in the steaming apparatus, 6 ounces of moisture were expelled, or 1.339 per cent.

In addition to the moisture, a heat of bright ignition expelled from specimen *a* 12.214 per cent. of volatile matter, and from *b* 17.777.

Two other specimens afforded to Dr. King a mean of 16.26 per cent. of volatile matter; and the mean of all the trials gives the total volatile matter of this coal 16.119 per cent.

The sulphur in specimen *a* was found to be 0.853 per cent.

Four trials on the incineration of each specimen gave for *a* 5.40, and for *b* 13.246 per cent. of ashes. Before the incineration was complete, the last specimen, when withdrawn from the muffle, was found to emit a very strong odor of sulphurous acid. The ashes produced at the lowest temperature were of a purplish-gray color; those which had been more strongly heated, were of a deeper red, and had small masses of oxide of iron scattered through them. The ashes of specimen *b* were of an entirely different character—being grayish white, and more dense than those of the other.

In burning 4,295 pounds of this coal, there were produced of ashes 290.46, and of clinker 189.75 pounds; or the former was 6.763, and the latter 4.418 per cent. of the coal burned—the total waste being 11.181 per cent.

The clinker is of a dark-brown color, having fragments of slaty residue intermixed, not remarkably porous, and considerably agglutinated. It weighs 30.87 pounds per cubic foot. The ashes weigh 44.5 pounds. The reincineration of ashes and clinker proved that the former had embraced 8.354 per cent., and the latter 0.436 per cent. of combustible; whence the absolute quantity of incombustible ingredients is 10.597 per cent.

The composition of the coal may be thus stated:

Moisture	1.339	per cent.
Sulphur	0.853	"
Other volatile matter	13.927	"
Earthy matter	10.773	"
Fixed carbon	73.108	"
	100.	

After four days' operations in burning this coal, there were obtained of soot 14 pounds, weighing at the rate of 12.06 pounds per cubic foot. This, when incinerated, gave 7.583 pounds of ashes, or 0.176 per cent. of the coal which is included in the *earthy matter* above given.

For the purposes of working iron, this coal will be found well adapted where a large hollow fire is not required. Sixty pounds of it were found sufficient to make 10 links of a chain 1⅜ inch in diameter. For domestic purposes it will be equally appropriate, where a lively fire of medium-sized flame is desired, and where a high intensity of combustion is not necessary. If used in close stoves, or house-heating furnaces, the amount and character of its residuum will probably be found to interfere with a satisfactory application.

This coal takes fire promptly; 50.5 minutes was the mean time required by it to bring the boiler to regular action, after the commencement of charging. It also burns up tolerably clean; having, as will be seen from the table of deductions, left on an average only 13.75 pounds of unburnt coke after each trial.

An experiment by the oxide of lead on specimen *a*, above analyzed, resulted in reducing 30.785 times the weight of coal employed. Deducting the earthly constituents, this gives 32.542 of lead to one of combustible matter of the coal.

TABLE LXXIX.—

First trial—upper damper 10 *inches open;*

	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of coal supplied to grate at each time.
2	[illegible]	[illegible]	0.16	-	-
2	0.516	5.41	0.20	-	104.50
3	0.540	5.17	0.29	-	[illegible]
3	0.555	5.02	[illegible]	540	-
3	[illegible]	5.02	0.40	1037	110.25
2	0.566	5.02	0 40	1687	102.50
3	0.560	[illegible]	0.41	2274	-
3	0.563	4.95	0.45	2782	114.50
3	0.555	5.02	0.40	3689	[illegible]
3	0.550	5.07	0.38	4417	-
3	0.551	5 06	0.38	5077	105.50
2	0.543	5.14	0.30	6179	107.50
0	0.548	5.10	0.38	6671	[illegible]
0	0.543	5.14	0.37	7079	-
0	0.548	5.09	0.39	7785	109.25
0	0.523	5.34	0.25	8362	-
8	0.527	5.31	0.25	8719	108.25
8	0.518	5.44	0.24	9137	-
1	0.495	9.62	0.20	9710	-
2	[illegible]	6.97	0.20	9722	-
1	0.347	7.06	-	9907	-

Period of steady action, from 7*h*. 50*m*. a. m. to 2*h*. 20*m*. p. m.=6*h*. 30*m*.; coal supplied to grate, same time, 865 5 pounds; water to boiler, 7,536 pounds; water to one of coal, 9.052.

BLOSSBURG COAL.

air plates closed; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	70.3	68	-	-	Small furnace in action; water 0.05 inch above normal level; commenced firing.
6.30	70.3	66	+ 6	-	Wood consumed, 146.5 pounds; commenced charging with coal; it takes fire promptly.
6.47	71.4	69	23	-	Steam blows off at 6*h*. 40*m*. a. m.
-	72.1	71	50	1.996	Tank partly filled at 7*h*. 40*m*.
7.50	73.2	88	49	2.633	
8.30	71.4	107	72	3.417	Filled tank at 8*h*. 15*m*.
-	70.7	121	80	3.109	
9.15	72.5	136	90	2.691	Placed 28 pounds of this coal in drying apparatus.
10.00	72.2	151	60	4.805	Smoke 18 seconds in reaching chimney top.
-	73.9	168	79	3.857	
11.10	73.3	184	78	2.622	Morning clear until this time; now cloudy; wind SW., brisk.
11.40	73.8	187	74	3.503	Filled tank at m.; fire out in small furnace, and its damper closed.
0.10	74.9	196	84	2.607	
-	75.2	201	76	3 242	
1.12	74.6	211	84	4.488	
-	76.9	217	52	2 711	Wind S., brisk; clear at 2*h*. 30*m*. p. m.
2.20	75.2	226	58	1.785	Contents of ash pit thrown on grate; dew point, by observation, 74°; by calculation, at same place, 75°.6.
-	72.8	222	62	2.225	Filled tank at 2*h*. 50*m*.; damper reduced to 5 inches at 3*h*. p. m.
-	72.8	213	6	-	Water in boiler left at 0.2 inch above normal level; wind SE., brisk; clear.
-	73.9	110	—42		
-	73.9	106	—23	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	55.75
Ashes	61.00
Ashes behind bridge	3.54
Total ashes and clinker	120.29
Deduct wood ashes	0.45
Total waste from coal	119.84
Coke	14.25

TABLE LXXX.—

Second trial—upper damper 5

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of coal supplied to grate at each time.
	h. m.													
	A. M.													
July 18	5.18	80	75.5	186	186	83	209	80	29.91	0.347	7.08	0.20	-	-
	5.45	80	75	176	252	83	222	80	29.91	0.533	5.24	0.22	-	104.25
	6.00	81	77	175	242	83	227	80	29.91	0.533	5 24	0.28	-	-
	6.30	81	77	180	270	83	228	80.5	29.91	0.533	5.24	0.28	152	106 00
	7.00	81	77	184	276	83	229	81	29.92	0.536	5.21	0 30	573	-
	7.30	81	77	196	276	83	229	83	29 92	0.539	5.18	0.30	1080	99.25
	8.00	83	77	208	300	83	230	83	29.92	0.543	5.14	0.37	1427	-
	8.45	85	78	228	290	83	230	84	29.92	0.540	5 16	0.40	1937	108.75
	9.15	87	78	238	300	84	230	86	29.92	0.541	5.16	0.38	2662	-
	10.00	93	78	254	300	83	230	87	29.92	0.541	5.16	0.40	3415	112.25
	10.25	90	77	262	302	84	230	88	29.92	0.548	5.10	0.44	3850	113 25
	11.25	93	77	280	290	84	228	89	29.92	0.517	5.40	0.32	4960	107.75
	P. M.													
	0.00	94	78	294	282	84	228	90	29.92	0.517	5.40	0.27	5635	-
	0.30	95	80	308	272	83	227	91	29.91	0.516	5.41	0.27	5975	107.00
	1.20	94	78	316	270	84	228	91	29.92	0.517	5.40	0.39	6497	-
	1.50	90	78	306	282	84	227	88	29.91	0.509	5.48	0.35	7149	110.00
	3.00	87	77	312	252	84	226	86	29.91	0.512	5.45	0 28	7697	-
	5.15	88	77	298	220	84	225	85	29.91	0.485	5.70	0.20	8149	-
	A. M.													
July 19	4.10	79.5	70	224	190	83	218	80	29.92	0.402	6.53	0.16	8154	-
	4.50	79	71	220	181	83	218	80	29.92	0.385	6.71	0.15	8312	-

Period of steady action, from *6h. 30m.* a. m. to *1h. 50m.* p. m. = *7h. 20m.*; coal supplied to grate in same period, 758.25 lbs.; water to boiler in same period, 6,997 lbs.; and to 1 of coal, 9.227.

BLOSSBURG COAL.

inches open; air plates closed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	73 9	106	+23	-	Water 0.07 inch above normal level; commenced firing; cloudy.
5 45	73.2	96	30	-	Wood consumed, 90.5 lbs; commenced charging with coal.
-	75.6	94	15	-	Steam blowing off.
6.30	75.6	99	42	0.805	Fire in full activity.
-	75.6	103	47	2.230	
7.30	75.6	115	47	2.686	
-	75.0	125	70	1.838	
8 15	75.8	143	60	1.801	
-	75.2	151	70	3 841	
9.15	73.6	161	70	2.659	
10.20	73.0	172	72	2 580	Set damper at 4 inches at 10*h*. 50*m*.; filled tank at 11*h*.;
11.25	72.1	187	62	2.940	wind NW., brisk; clear; second weight taken from back valve, to allow part of the steam to escape in that direction,
-	72.3	200	54	3.065	and prevent priming.
0.30	75 9	213	45	1.801	
-	72.8	222	42	1.659	Second weight replaced on back valve.
1.50	74.4	216	57	3.454	Filled tank at 1*h*. 50*m*. p. m.
-	73.8	225	26	1.244	Contents of ash pit thrown on grate.
-	73 5	210	— 5	-	Water in boiler left at 0.3 inch above normal level.
-	65.1	144.5	—28	-	Water in boiler 0.1 inch below normal level.
-	67.6	141	—31	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	40.75
Ashes	72.50
Ashes behind bridge	2.90
Total ashes and clinker	116.15
Deduct wood ashes	0.278
Total waste from coal	115.872
Coke	12.25

TABLE LXXXI.—

Third trial—upper damper 10

Period of steady action this day, from 7*h*. 15*m*. a. m. to 2*h*. 15*m*. p. m. = 7*h*. Coal supplied to grate, same period, 716.25 lbs.; water to boiler, 6,928 lbs.; or, to 1 of coal, 9.672.

BLOSSBURG COAL.

inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of surface of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	67.6	141	— 34	-	Water 0.16 inch above normal level; wind W., clear; commenced firing.
5.50	67.2	122	+ 24	-	Wood consumed, 70¾ lbs.; steam at equilibrium; commenced charging with coal.
-	70.3	120	11	-	Steam blows off.
6.10	70 0	121	78	1.669	Air plates opened, back valve double weighted.
-	71.0	124	119	1.849	Fire active; extra weight removed from back valve; steam escapes from both valves.
7.15	71.8	134	99	3.873	
8.00	71.5	143	102	2.199	
-	73.5	152	100	2.622	
9.00	73.2	161	109	3.232	Filled tank.
-	73.5	170	104	1.791	Wind NW., light; clear.
-	73 2	177	100	2.935	
10.30	73.0	185	99	1.791	
-	72.7	184	103	2.278	
11.15	72.7	193	81	3.481	Rise of temperature of water in tank probably due to the escape of steam into it, through leakage of the cocks of the filling apparatus.
0.00	75.2	194	94	3.030	
-	73.8	204	93	3.073	
1.00	73.6	205	89	2.305	Filled tank.
-	75.5	221	77	2.032	
2.15	69.4	221	100	2.857	Wind SW., strong.
-	70.3	223	40	1,833	Damper reduced to 4 inches; air plates closed, and back valve loaded at 2*h*. 50*m*. p. m.; contents of ash pit thrown on grate; water at 4*h*. 40*m*. p. m. left 0.4 inch above normal level.
-	74.6	207	12		
-	59.3	146	— 12	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	44.00
Ashes	60.25
Ashes behind bridge	3.11
Total clinker and ashes	107.36
Deduct wood ashes	0.217
Total waste from coal	107.143
Coke	9.25

TABLE LXXXII.—

Fourth trial—upper damper 4

Date.	Hour.	Temperatures of the							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m. A. M.													
July 20	5.15	72	64	218	206	84	218	-	29.94	0.409	6.48	0.16	-	-
	5.48	73	65	208	270	84	228	74	29.94	0.533	5.24	0.26	-	100.75
	6.20	74	65	198	268	84	231	74	29.94	0.529	5.28	0.29	149	102.75
	7.25	74	66	224	290	84	230	74	29.97	0.529	5.28	0.30	906	-
	8.00	76	66	244	296	84	230	74	29.97	0.531	5.26	0.30	1454	105.25
	8.30	78	66	260	300	83	230	75	29.98	0.520	5.37	0.28	1949	-
	9.10	81	71	276	290	83	230	76	29.98	0.520	5.37	0.27	2344	104.75
	9.50	80	67	286	292	79	230	77	29.98	0.520	5.37	0.30	2764	105.75
	10.30	80	65	292	294	78	231	78	30.01	0.532	5.25	0.30	3274	-
	11.00	81	65	300	294	78	231	79	30.00	0.532	5 25	0.28	3529	-
	11.30	80.5	64	302	302	78	231	78	30.01	0.530	5 27	0.30	3946	112.00
	P. M.													
	0.10	86	68	292	280	78	231	79	29.99	0.521	5.36	0.28	4662	-
	0.40	82	64	302	298	78	231	79	29.99	0.530	5.27	0.28	5129	108.00
	1.30	80	64	310	300	78	231	79	30.00	0.527	5.30	0.27	5824	107.25
	2.00	83	64	308	320	78	232	79	29.98	0.535	5.22	0.30	6244	-
	2.30	84	68	314	298	78	232	79	29.97	0.532	5.25	0.28	6578	-
	3.00	83	65	314	292	78	232	79	29.97	0.541	5.16	0.29	6929	108.25
	3.45	85	66	318	295	82	232	79	29.97	0 531	5.26	0.27	7536	-
	4.30	82	64	318	294	82	232	78.5	29.98	0.535	5 22	0.28	8151	105.00
	5.00	82	64	306	338	82	232	78 5	29.97	0.539	5.18	0.28	8459	-
	5.30	84	66	312	288	82	232	79	29.98	0.535	5.22	0.28	9084	107.00
	6.00	81	64	318	282	82	232	79	29.98	0.527	5.30	0.25	9329	-
	6.10	79	62	318	274	82	230	79	29.99	0.525	5.32	0.24	9737	-
	A. M.													
July 21	6.00	66	57.5	216	209	79	218	67	30.04	0.405	6.51	0.14	10061	-

Period of steady action, from 7*h*. 50*m*. a. m. to 5*h*. 7*m*. p. m. = 9*h*. 17*m*.; coal supplied to grate, 858 lbs.; water to boiler, 7,331 lbs.; or, to 1 of coal, 8.522.

BLOSSBURG COAL.

inches open; air plates half open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	59.3	146	—12	-	Water in boiler 0.15 inch above normal level; fire in small furnace; valves double weighted.
5.48	60.6	135	+42	-	Wood consumed, 69 lbs.; commenced charging with coal; second weights removed from valves; steam blows off;
6.20	60.1	121	37	0 740	coal takes fire promptly.
-	65.1	150	60	1.851	Wind NE.; cloudy.
7.50	60.8	168	66	2.489	
-	59.8	182	70	2.622	
9.00	66.9	195	60	1.569	
9.50	60.7	206	62	1.669	
-	57.1	212	63	2.026	Wind NW., brisk; cloudy.
-	56 6	219	63	1.351	Commenced drawing gases from lower flue at 11*h*. 29*m*.
11.30	54.9	221.5	71	2 209	a. m; drew in 33 minutes 101 cubic inches, which gave water 0.77 grain, carbonic acid 5.24 grains, and 12.537 cubic inches of oxygen.
-	59.9	206	49	2.819	Wind NE., brisk; clear.
0 20	54.2	220	67	2 474	
1.15	55 2	230	69	2 209	
-	53 7	225	88	2 225	
-	57.1	230	66	1.769	
2.45	55 6	231	60	1 859	Filled tank; coal in drying apparatus weighs 26 lbs. 10 oz.
-	56.6	233	63	2.211	
3.55	54.2	236	62	2.105	Commenced drawing gases from lower flue at 4*h*. 28*m*. p.
-	54.2	224	106	1.791	m.; drew in 37 minutes 100 cubic inches, which gave water 0.82 grain, carbonic acid 4.72 grains, oxygen 11.939 cubic inches.
5.07	57.1	228	56	3.152	Contents of ash pit thrown on grate; air plates closed.
-	54.7	237	50	1.314	
-	51.7	239	44	-	Water in boiler left at 1.10 inch above normal level.
-	50.6	150	— 9	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	49.25
Ashes	84.875
Ashes behind bridge	3.45
Total clinker and ashes	137.575
Deduct wood ashes	0.212
Total waste from coal	137.363
Coke	19.25
Soot, (4 burnings)	14.00

TABLE LXXXIII.—DEDUCTIONS FROM

Experiments on Blos

	Nature of the data furnished by the respective tables.	1st Trial. (*Table LXXIX.*)	2d Trial. (*Table LXXX*)
		July 17.	*July* 18.
1	Total duration of the experiment, in hours	24.467	23.533
2	Duration of steady action, in hours	6.50	7.333
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	11.0	9.0
7	Total weight of coal supplied to grate, in pounds	1184.25	968.5
8	Pounds of coal actually consumed	1170.0	956.25
9	Pounds of coal withdrawn and separated after trial	14.25	12.25
10	Mean weight, in pounds, of one cubic foot of coal	53.829	53.805
11	Pounds of coal supplied per hour, during steady action	133.15	103.44
12	Pounds of coal per square foot of grate surface, per hour	9.463	7.352
13	Total waste, ashes and clinker, from 100 pounds of coal	10.2426	12.117
14	Pounds of clinker alone, from 100 pounds of coal	4.747	4.252
15	Ratio of clinker to the total waste, per cent.	46.345	35.09
16	Total pounds of water supplied to the boiler	9907.0	8312.0
17	Mean temperature of water, in degrees Fahrenheit	80°.0	83°.5
18	Pounds of water supplied at the end of experiment, to restore level	197.0	163.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	23.0	20.0
20	Pounds of water evaporated per hour, during steady action	1205.53	954.58
21	Cubic feet of water per hour, during steady action	19.28	15.27
22	Pounds of water per square foot of heated surface per hour, by one calculation	3.193	2.528
23	Pounds of water per square foot, by a mean of several observations	3.153	2.546
24	Water evaporated by 1 of coal, from initial temp. (a) final result	8.4495	8.6713
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	9.053	9.227
26	Pounds of fuel evaporating one cubic foot of water	7.3969	7.2077
27	Mean temperature of air entering below ash pit, during steady pressure	84°.86	88°.23
28	Mean temp. of wet bulb thermom., during steady pressure	76°.36	77°.69
29	Mean temperature of air, on arriving at the grate	246°.57	250°.31
30	Mean temperature of gases, when arriving at the chimney	299°.14	285°.38
31	Mean temperature of steam in the boiler	229°.43	228°.77
32	Mean temperature of attached thermometer	82°.93	86°.27
33	Mean height of barometer, in inches	30.016	29.918
34	Mean number of volumes of air in manometer	5.09	5.265
35	Mean height of mercury in manometer, in atmospheres	0.5483	0.5305
36	Mean height of water in syphon draught gauge, in inches	0.3633	0.3491
37	Mean temperature of dew point, by calculation	73°.56	74°.49
38	Mean gain of temperature by the air, before reaching grate	161°.71	162°.08
39	Mean difference between steam and escaping gases	73°.91	58°.0
40	Water to 1 of coal, corrected for temperature of water in cistern	8.4181	8.635
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.4973	9.7123
42	Pounds of water, from 212°, to 1 cubic foot of coal	511.23	522.57
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.5811	11.0515
44	Mean pressure, in atmospheres, above a vacuum	1.4552	1.4134
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.723	6.1053
46	Condition of the air plates at the furnace bridge	Closed.	Closed.
47	Inches opening of damper, (U. upper)	U. 10	U. 5

TABLES LXXIX, LXXX, LXXXI, LXXXII.

burg (Pennsylvania) coal.

3d Trial. (*Tab. LXXXI.*)	4th Trial. (*Tab. LXXXII.*)	Averages.	Remarks.
July 19.	*July* 20.		
24 0	24.75		
7.0	9.283		
14.07	14.07		
377.5	377.5		
18.75	18.75		
10 0	11 0		
1030.5	1166.75		
1021.25	1147.5		
9.25	19.25	13.75	Combustion, with a four-inch damper, in the 4th trial, favored, as in many other cases, the leaving of a larger amount than usual of unburnt coke.
51.5275	53.031	53.0489	
108.56	92.427	109 394	
7.715	6.569	7.775	
10.491	11.965	11.2039	
4.3006	4.285	3.3961	
40.992	35 797	39.556	
9058.0	10061.0		
85°.5	80°.6		
174.0	324.0		
22.0	43.0		
980.0	788.64	982.19	
15.68	12.46	15.672	The rate of evaporation, during the 1st trial, of 19.28 cubic feet of water per hour, was scarcely exceeded by any coal tried during the course of these experiments.
2.621	2.098	2.610	
2.587	2.128		
8 8479	8.7302	8 6747	
9 027	8.522	8.957	
7.0639	7.169	7.2069	
89°.29	80°.825		
76°.98	65°.60		
271°.0	239°.70	264°.395	
327°.64	295°.55	301°.93	The 3d and 4th trials, with open air plate, show a higher mean temperature in the escaping gases, by about 19°, than the 1st and 2d trials, with the plate closed. The combustion of gases, at or beyond the bridge, would naturally produce this effect.
231°.21	231°.15		
86°.64	77°.65		
29.912	29.981		
5.317	5.272		
0.5253	0.5298		
0.3377	0 2806	0.3327	The strong draught of the chimney, on the 1st trial, was probably aided in some degree by the prevalence of a brisk westerly wind.
73°.43	57°.725		
181°.71	208°.875	178°.594	
97°.0	67°.18	74°.02	
8.8102	8.6967	8.6401	
9.8922	9.8062	9.7245	
509.72	520.06	515.89	
11.0514	11.139	10.9557	The 2d and 3d trials give results differing only by 1, in the fourth place of decimals. The slow combustion of the 4th trial appears to have favored economy.
1.3997	1.3973	1.4164	
5.9026	5.8676	6.1490	
Open.	Half open.		
U. 10	U. 4		

No. 9.

Coal from Archibald McIntyre's mines, near Ralston, Lycoming county, Pennsylvania.

This coal was accompanied by no certificate or description stating its locality, or the time of mining it. The markings of the casks were relied upon for indicating its origin.

In external characters it strongly resembles the coal of Blossburg, and perhaps even more nearly that of Quin's run.

It is deep black and brilliant in both the main and cross partings. The main partings are generally inclined to the surfaces of deposition in angles of 85° and 95°. Very brilliant and alternately rather dull lines of black mark the edges of the strata. It breaks into columnar masses, exposing little or nothing which could indicate the nature or amount of its impurities.

It came to hand mostly in the state of small lumps, or fine; was noticed as having the brighter portions in a crystalloid form, and being of a friable texture.

Its specific gravity, as determined from two specimens, was 1.3949 and 1.3807, from which the calculated weight per cubic foot is 86.74 pounds; while 29 trials in the charge box gave the actual weight 55.379 pounds per cubic foot—equal to 0.6384 of the calculated weight; the least being 52.5, and the greatest weight 57.25 pounds. This proves the bulk of a ton to be 40.449 cubic feet.

The moisture in specimen *a*, above referred to, was 0.54, and that in *b* 0.601 per cent.

The trial of 28 pounds proved the moisture to be 0.67 per cent.

The sulphur in specimen *b* was found to be 0.0303 per cent.

The total volatile matter, other than water, was in specimen *a* 15.149, and in *b* 15.137. Five trials on two other specimens by Dr. King resulted in giving a mean of 13.3 as the total amount of volatile matter.

The mean of the two sets, or 14.507, is probably a fair representative of this ingredient of the coal.

The two specimens were tried each four times, for the amount of earthy residua: *a* gave a mean of 11.96, and *b* of 8.7 per cent. The ashes from these analyses are almost perfectly white.

During the three trials of its evaporative power, there were consumed of this sample 3,073.25 pounds; and of waste, in the form of ashes, there were left 420.882 pounds, and of clinker exactly 100 pounds. The former are 13.69, and the latter 3.25 per cent. of the coal.

The clinker weighs 34.37 pounds per cubic foot, and is variously colored, having undergone but little fusion, except on the surfaces of some of the silicious portions. The shaly portions retain nearly their original form, and appear to have merely parted with their carbonaceous matter.

The ashes from the furnace weigh 37.79 pounds per cubic foot, and present a gray color, showing numerous minute fragments of coal intermixed.

The soot, of which 11.5 pounds were collected after three days' burning, weighed 16 29 pounds per cubic foot.

The clinker did not adhere to the grate, or cause any remarkable ob-

struction to the combustion, other than what might be expected from its considerable bulk.

Reincineration reduced the ashes 20.95, the clinker 9.93, and the soot 45.56 per cent. of their respective weights.

The composition of this coal may, therefore, be stated as follows:

Moisture, from drying 28 pounds - - - - -	0.670
Sulphur, from 1 specimen - - - - -	0.030
Other volatile matter, from 4 specimens - - - -	13.807
Earthy matter, from 3,073.25 pounds - - - -	13.961
Fixed carbon, by difference - - - - -	71.532
	100.

Volatile to fixed combustible 1:5.181.

The ignition of this coal appears to be effected with rather more difficulty than that of some others of the free-burning class. It took 1.722 hour to bring the boiler to a steady rate of evaporation; and there were left, on an average, 46.25 pounds of unburnt coke at the end of each experiment.

In burning, it produced a tolerably dense reddish flame; caked considerably; sent off a moderate quantity of smoke; but only caused a visible current at the chimney top during the application of fresh coal to the grate, and for one or two minutes following.

The heating power of this coal was tried by the oxide of lead on specimen *b*, above analyzed.

Twenty grains reduced 596.64 of metallic lead, or 29.832 times the weight of coal; which, after deducting 9.301, the amount of ashes and moisture in 100 parts of that specimen, gives the reductive power of the combustible matter of this coal 32.891, which is about the same as that of several anthracites tried by the same means. When tried in the smith shop for chain cables, this coal yielded results far from satisfactory.

The cinder was very abundant, and difficult of fusion; the coke hard and unmanageable after the flame had ceased. In the anchor shop it was found equally objectionable by the workmen who tried it. The fire, it was said, could not be kept hollow, notwithstanding the hardness of the coke, and the large quantity of incombustible matter impeded the blast.

Not being a full sample, there was not a sufficient quantity left of this coal to make any trials in grates for domestic purposes. This is the less to be regretted, since its heating power was fully ascertained by other means; and the amount and quality of its residue after incineration sufficiently indicate its adaptedness to these purposes. No danger can, in general, be apprehended from the clogging of grates by slag at the moderate temperatures employed in open office or parlor fires.

The appearance of the residua left, after reincinerating the waste materials of this coal, is very remarkable. Not a trace of redness is visible in that from the cinder. A grayish white is the color of the reduced ashes, and a light red predominates in the residue from the soot. It was remarked, in reincinerating the latter, that the part of the ashes left which was at the top, became of about the color of wood ashes; while the lower parts, near the bottom of the platinum basin, were reddish brown.

TABLE LXXXIV.—L

First trial—upper damper 10 *inches open; a*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 23	4.50	74	69	155	-	82	210	-	30.06	0.3515	7.04	0.11	-	-
	5.15	74	69	155	-	82	210	-	30.06	0.352	7.04	0.11	-	-
	6.10	76	70	155	236	82	226	-	30.08	0.511	5.46	0.22	-	109.75
	6.25	75.5	70	160	200	82	228	-	30.08	0.521	5.36	0.21	-	113.00
	7.00	75	70	155	260	82	231	-	30.09	0.536	5.21	0.26	170	-
	7.30	77	71	160	272	82	232	-	30.10	0.545	5.12	0.28	432	-
	8.00	78	71	170	265	82	232	-	30.09	0.541	5.16	0.30	767	105.00
	8.30	80	71.5	182	274	82	232	-	30.09	0.537	5.20	0.26	1197	-
	9.00	81	73	202	260	82	232	-	30.08	0.533	5.24	0.25	1532	-
	9.30	82	73	226	252	82	231	-	30.08	0.531	5.26	0.25	1872	113.25
	10.00	84	72	234	286	82	232	-	30.08	0.539	5.18	0.30	2214	-
	10.30	85	72	236	-	82	232	-	30.08	0.553	5.04	-	2555	113.00
	11.00	86	72	238	286	83	232	-	30.07	0.545	5.12	0.32	3109	-
	11.30	87.5	74	255	272	83	232	-	30.06	0.535	5.22	0.30	3522	109.25
	P. M.													
	0.00	87	75	268	278	84	232	-	30.06	0.541	5.16	0.31	3755	-
	0.30	89	73	276	-	84	232	-	30.06	0.549	5.08	-	4255	-
	1.00	89	74	269	288	85	232	-	30.05	0.535	5.22	0.31	4665	112.00
	1.30	89.5	75.5	280	286	88	232	-	30.06	0.541	5.16	0.36	4912	-
	2.00	91	76	284	290	89	232	-	30.03	0.537	5.20	0.31	4912	108.50
	2.30	92	75	294	276	89	231	-	30.02	0.527	5.30	0.25	5880	-
	3.00	92	76	298	282	89	232	-	30.02	0.539	5.18	0.30	6300	106.50
	3.30	93	76	296	300	89	232	-	30.01	0.531	5.26	0.29	6800	-
	4.00	94	76	300	304	88	232	-	30.01	0.523	5.34	0.27	7040	-
	4.30	93	75	310	268	89	230	-	29.99	0.513	5.44	0.24	7555	110.25
	5.00	94	76	320	250	89	230	-	30.00	0.499	5.58	0.22	7890	-
	5.20	91	74	338	232	89	228	-	30.00	0.485	5.70	0.23	8330	-
	A. M.													
June 24	5.00	81	73.5	224	180	88	224	-	29.95	0.450	6.06	0.12	8330	-
	5.20	80	73.5	212	185	88	222	-	29.95	0.446	6.08	0.12	8403	-

Period of steady action, from 7*h.* 50*m.* a. m. to 4*h.* 25*m.* p. m.=8*h.* 35*m.*; coal supplied to the grate in the same time, 772.75 lbs.; water to boiler, 6,814 lbs.; or, to 1 of coal, 8.818.

OMING CREEK COAL.

lates closed, and steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	66.6	81	-	-	Manometer indicates only atmospheric pressure; attached thermometer 76°; water at normal level.
-	66.6	81	-	-	Commenced firing.
6.10	67.3	79	+10	-	Wood consumed, 107½ lbs.; steam at equilibrium; commenced charging with coal.
6.25	67.5	84.5	—28	-	Steam begins to blow off.
-	67.7	80	+29	0.772	
-	68.4	83	40	1.388	28 lbs. of this coal placed in drying apparatus.
7.50	68.0	92	33	1.775	
-	68.0	102	44	2.278	Wind W., light; clear; atmosphere becoming hazy.
-	70.0	121	28	1.775	
9.20	69.6	144	21	1.801	Dew point, by observation, 69°.5.
-	67.3	150	54	1.812	Commenced drawing gases at 10h. 22m. a. m.; drew in 17 minutes 50 cubic inches, which gave 0.44 grain water,
10.35	67.0	151	-	1.807	carbonic acid 1.74 grain, oxygen 7.575 cubic inches; fire
-	67.0	153	54	2.935	in average action.
11.30	67.0	167.5	40	2.188	Dew point, by observation, 67°.5.
-	70.9	181	46	1.234	Tank partly filled.
-	67.2	187	-	2.649	Commenced drawing gases 2d time, (fire in free burning condition;) drew in 15 minutes (commencing at 0h. 25m.
0.50	68.8	180	56	2.172	p. m.) 100 cubic inches, which gave water 1.19 grain,
-	70.9	190.5	54	-	carbonic acid 5.87 grains, oxygen 10 cubic inches;
2.00	71.2	193	58	-	Filled tank; water in boiler fell to 1.5 inch below normal
-	69.4	202	45	2.146	level.
3.00	69.4	206	50	2.225	
-	70.6	203	68	2.649	
-	70.3	206	72	1.271	
4.25	69.1	217	38	2.728	Smoke at the top of the chimney, during this experiment, only when stoking.
-	70.3	226	20	1.775	Contents of ash pit thrown on grate; weather during the day clear; wind W., light.
-	68.1	247	4	-	Water in boiler left at 1.5 inch above normal level; damper set at 3 inches.
-	70.7	143	—44		
-	71.0	132	—37	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	30.75
Ashes	127.25
Ashes behind bridge	6.01
Total clinker and ashes	164.01
Deduct wood ashes	0.329
Total waste from coal	163.681
Coke	57.78

TABLE LXXXV.—LY

Second trial—upper damper 10 *inches open;*

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 24	5.20	80	73.5	212	185	88	222	-	29.95	0.446	6.08	0.12	-	-
	5.40	81	75	204	214	88	225	-	29.94	0.525	5.31	0.18	-	111.50
	6.10	80	74	192	222	88	228	-	29.94	0.532	5.25	0.30	-	106.25
	6.40	80	74	196	308	88	230	-	29.94	0.536	5.2	0.30	254	-
	7.10	80	74	193	332	88	231	-	29.94	0.540	5.17	0.30	739	-
	7.45	81	74	206	335	81	233	-	29.94	0.558	5.00	0.38	1207	111.50
	8.15	82.5	75	214	355	80	283	-	29.94	0.560	4.98	0.40	1207	109.50
	8.45	85	76	226	334	80	232	-	29 91	0.538	5.20	0.32	2347	-
	9.15	84	76	234	312	80	232	-	29.91	0.542	5.15	0.36	2599	-
	9 45	88	78	248	308	80	232	-	29 92	0.539	5.19	0 33	3107	108.50
	10.15	90	77	256	280	80	231	-	29.91	0.535	5 22	0.33	3379	-
	10.45	89	77	262	292	80	231	-	29.91	0.530	5.28	0.30	3737	107.50
	11.15	90	77	268	298	80	232	-	29.90	0.544	5.14	0.38	4280	-
	11.45	90	76.5	270	306	80	232	-	29.89	0.539	5.18	0.36	4798	108.75
	P. M.													
	0.15	90	77	272	280	83	239	-	29.87	0.516	5.42	0.28	5280	-
	0.45	86	76	280	-	83	232	-	29.87	0.548	5.10	0.40	5668	-
	1.30	82	75	282	330	84	232	-	29.89	0.550	5.07	0.38	6054	114.25
	2 00	85	77	280	312	84	231	-	29.86	0.533	5.24	0.30	6764	-
	2.30	84	76	284	292	84	231	-	29.86	0.533	5.24	0.30	7184	114.50
	3.15	84	75	310	255	84	229	-	29.85	0.527	5.30	0 25	7644	-
	A. M.													
June 25	10.15	79	68	170	182	81	210	-	30.01	0.347	7.08	0.12	7644	-
	10.45	79	69	169	188	81	208	-	30.02	0.347	7.08	0.12	8064	-

Period of steady action, from 7*h*. 30*m*. a. m. to 2*h*. 30*m*. p. m.=7 hours; coal supplied to grate, 663 lbs.; water to boiler, 5,977 lbs.; or, to 1 of coal, 9.015.

COMING CREEK COAL.

air plates open, and steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
A. m.					
-	71.0	132	—37	-	Commenced firing; water in boiler 0.1 inch above normal level.
5.40	72.8	123	—11	-	Wood consumed, 59 lbs.; steam at equilibrium; commenced charging with coal.
6.10	71.7	112	— 6	-	Steam begins to blow off; air plates opened; damper set at 10 inches; Wind SW., brisk; clear.
-	71.7	116	+78	1.346	
-	71.7	113	161	2.569	Dew point, by observation, 72°.
7.30	71.4	125	102	-	Commenced filling tank at 7*h.* 30*m.*
8.25	72.3	131.5	122	-	Water in boiler 0.6 inch below normal level; tank filled.
-	73.0	141	102	2.687	
-	73.3	150	80	1.335	
9.35	74.9	160	76	2.691	
-	73.0	166	49	1.441	
10.45	73.2	173	61	1.897	
-	73.0	178	66	2.686	Wind S., fresh; clear.
11.35	72.2	180	74	2.744	Tank partly filled at 12 m.; commenced raining at 0*h.* 45*m.* p. m.; wind W., strong.
-	73.0	182	51	2.554	Commenced drawing gases at 0*h.* 41*m.*; drew in 16 minutes 100 cubic inches, which gave water 1.42 grain, carbonic acid 5.27 grains, oxygen 12.22 cubic inches; draught reduced by allowing some of the steam to escape from back valve.
-	72.7	194	-	2.056	
1.00	72.2	199	98		
-	74.4	195	81	2.318	Scarcely any smoke observed at chimney top to-day; still raining.
2.30	73.3	200	61	2.172	
-	71.8	226	26	-	Air plates closed; contents of ash pit on grate; damper set to 5 inches; water 0.7 inch above normal level.
-	62.8	91	—28	-	One of the ash pit doors left half open during the night; manometer shows atmospheric pressure.
-	61.5	90	—20	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	33.75
Ashes - - - - - - - - - -	111.50
Ashes behind bridge - - - - - - - - -	5.66
Total clinker and ashes - - - - - - - -	155.91
Deduct wood ashes - - - - - - - -	0.181
Total waste from coal - - - - - - - -	155.729
Coke - - - - - - - - - -	113 18

TABLE LXXXVI.—LY

Third trial—upper damper 5 inches open; air plates open; steam

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 26	5.20	70	66.5	140	158	80	183	-	30.00	0.353	7.02	0.11	-	-
	6.25	70.5	67	138	190	80	202	-	30.02	0.386	6.70	0.17	-	-
	7.10	72	68	144	232	80	226	-	30.04	0.514	5.42	0.20	-	110.25
	7.25	72	68	144	244	80	228	-	30.04	0.520	5.36	0.20	-	-
	8.00	72	68	148	214	80	229	-	30.05	0.533	5.24	0.20	260	114.50
	8.30	75	70	160	252	80	230	-	30.05	0.528	5.20	0.20	700	-
	9.00	75	71	172	248	80	230	-	30.05	0.530	5.28	0.20	860	114.00
	9.30	77	72	180	256	80	230	-	30.05	0.540	5.18	0.20	1102	-
	10.00	82	72.5	194	258	80	230	-	30.05	0.535	5.22	0.20	1430	-
	10.30	83	73.5	200	260	80	230	-	30.05	0.530	5.28	0.22	1595	112.00
	11.00	82.5	72	208	272	80	230	-	30.05	0.533	5.24	0.22	2171	-
	11.30	83	72	212	268	80	230	-	30.05	0.530	5.28	0.21	2431	-
	P. M.													
	0.00	84.5	72.5	216	272	80	230	-	30.05	0.541	5.16	0.21	2686	108.25
	0.30	85	73	220	262	80	230	-	30.04	0.530	5.28	0.21	3021	-
	1.00	85	73	226	265	80	229	-	30.01	0.533	5.21	0.21	3271	109.00
	1.45	88	74	240	260	80	229	-	30.03	0.526	5.31	0.21	3789	-
	2.30	88	72	245	260	80	230	-	30.03	0.520	5.38	0.23	4294	113.00
	3.00	89	73	248	276	80	230	-	30.02	0.532	5.26	0.23	4699	-
	3.30	89	73	254	280	80	230	-	30.02	0.532	5.26	0.23	5026	-
	4.00	89	74	258	262	80	232	-	30.02	0.510	5.15	0.24	5315	110.75
	4.30	90	73	264	270	87	230	-	30.01	0.539	5.18	0.24	5621	-
	5.00	89	74	266	280	87	230	-	30.01	0.535	5.22	0.24	5961	114.00
	5.30	87	77	274	275	87	230	-	30.01	0.534	5.24	0.25	6471	-
	6.00	87	75	280	300	87	230	-	30.02	0.532	5.26	0.34	6641	-
	6.30	88	74	278	298	87	230	-	30.02	0.541	5.16	0.30	6981	114.50
	6.50	88	76	300	252	87	234	-	30.02	0.536	5.20	0.34	7392	-
	A. M.													
June 27	7.00	79.5	72	210	200	85	226	-	30.09	0.485	5.71	0.16	7396	-
	7.35	78	72	208	192	85	220	-	30.08	0.418	6.38	0.16	8121	-

The period of steady action, from *9h.* a. m. to *6h. 15m.* p. m.=*9h. 15m.*; coal supplied to grate, same time, 781.5 lbs.; water supplied to the boiler, 5,951 lbs.; and to 1 of coal, 7.615.

COMING CREEK COAL.

thrown out of back valve, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
+	64.6	70	—25	-	¾ inch below nor- in the boiler.
+	65.1	67 5	—12	-	
7.10	66.0	72	+.6	-	equilibrium; com-
-	66.0	72	16	-	NE., cloudy; dew
7.45	66.0	76	15	1.181	
+	67.7	85	22	2.331	
9.00	69.2	97	18	0.848	Wind NW., clear; steam from back valve driven into the building, raising the dew point.
-	60.9	108	26	1.282	
+	68.8	112	28	1.736	Wind E., clear.
10.20	69.9	117	30	0.874	Filled tank; dew point, by observation, 69°.5.
-	67.9	125.5	42	3.052	
-	67.7	129	38	1.377	Wind W., clear.
0.05	67.8	131.5	42	1.351	
-	68.5	135	32	1.775	
1.00	[redacted]	141	36	1.325	
-	69 1	152	31	1.829	
2.25	65.9	157	30	1.764	Wind E., clear.
+	[redacted]	159	46	2.146	
+	67.2	165	50	1.732	
3.45	68.8	169	30	1.531	Filled tank at 4*h.* 5*m.* p. m.; dew point, by observation, 69°; commenced drawing gases at 3*h.* 46*m.*; drew, in 10 minutes, 100 cubic inches, which gave water 0.96 grain, carbonic acid 5.32 grains, oxygen 8.87 cubic inches.
+	66.8	174	40	1.621	
5.07	68.8	177	50	1.801	
-	73.8	187	45	2.702	Pavement sprinkled with water, causing high dew point.
-	70.9	193	70	0.901	Steam thrown into chimney.
6.15	69.1	190	68	1.775	Air plates closed.
-	72.1	212	16	-	Contents of ash pit thrown on grate; water in boiler left at 1 inch above normal level.
-	69.0	130.5	—26	-	Water 1 3 inch below normal level.
-	69.5	130	—26	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	30.50
Ashes	165.50
Ashes behind bridge	6 08
	202.08
Deduct wood ashes	0.608
Total waste from coal	201.472
Coke	67 79
Soot, (3 burnings)	11.50

TABLE LXXXVII.—DEDUCTIONS

Experiments on Lycoming

No.		1st Trial (Tab. LXXXIV.)	2d Trial. (Tab. LXXXV.)
		June 23.	*June 24.*
		24.50	29.333
		[redacted]	7.0
		14.07	[redacted]
		377.5	377.5
		18.75	18.75
		10.0	[redacted]
		1099 5	992.25
		1041.72	979.07
		57.76	13.18
		54.975	[redacted]
		90.029	[redacted]
		6.398	6.7317
		15 712	15.905
		2.9461	3.9532
		[redacted]	[redacted]
		[redacted]	8064.0
		85°.2	82°.5
18	Pounds of water supplied at the end of experiment, to restore level - - - - - - - -	73.0	470.0
19	Deduction for temperature of water supplied at end of experiment, in pounds - - - - -	9.0	60.0
20	Pounds of water evaporated per hour, during steady action -	793.86	[redacted]
21	Cubic feet of water per hour, during steady action - -	12.7	12.66
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - - -	[redacted]	2.263
23	Pounds of water per square foot, by a mean of several observations - - - - - - -	2.111	2.261
24	Water evaporated by 1 of coal, from initial temp. (a) final result	8.0576	8.176
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action - - - - - - -	8 618	9.015
26	Pounds of fuel evaporating one cubic foot of water - -	7.7565	7.6453
27	Mean temp. of air entering below ash pit, during steady pressure - - - - - - - - -	85°.84	85°.47
28	Mean temp. of wet bulb thermometer, during steady pressure	73°.42	75°.21
29	Mean temperature of air, on arriving at the grate - -	243°.32	218°.19
30	Mean temperature of gases, when arriving at the chimney -	278°.29	311°.6
31	Mean temperature of steam in the boiler - - -	231° 81	231°.5
32	Mean temperature of attached thermometer - - -	82°.84	82°.47
33	Mean height of barometer, in inches - - - -	30.06	29.904
34	Mean number of volumes of air in manometer - -	5 192	5.174
35	Mean height of mercury in manometer, in atmospheres -	0 5378	0.5401
36	Mean height of water in syphon draught gauge, in inches -	0 292	0.3143
37	Mean temperature of dew point, by calculation - -	66°.88	72°.63
38	Mean gain of temperature by the air, before reaching grate -	157°.48	162°.72
39	Mean difference between steam and escaping gases - -	46°.2	79°.46
40	Water to 1 of coal, corrected for temp of water in cistern -	8.0234	8.1415
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern and boiler - - - - -	9 0112	9.1643
42	Pounds of water, from 212°, to 1 cubic foot of coal - -	495.39	505.18
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	10.691	10.8976
44	Mean pressure, in atmospheres, above a vacuum - -	1.4263	1.4318
45	Mean pressure, in pounds per sq inch, above atmosphere -	6.2956	6.2765
46	Condition of the air plates at the furnace bridge - -	Closed.	Open.
47	Inches opening of damper, (U. upper) - - -	U. 10	U. 10

FROM TABLES LXXXIV, LXXXV, LXXXVI.

creek (Pennsylvania) coal.

3d Trial. (Tab. LXXXVI.)	Averages.	Remarks.
June 26.		
26.25		
9.25		
14.07		
877.5		
18.75		
10.0		
1120.25		
1052.46		
67.79	46.25	With a 5-inch damper, "throttling" to some extent the flues, the combustion left 67.79 lbs. of unburnt coke; on the 2d trial, with a 10-inch damper, the quantity left was but about one-fifth as much.
56.012	55.371	
82 263	89.002	
5.847	6.3256	
19.143	16.920	
2.8866	3.262	
15.079	19.568	
8121.0		
82°.4		
730.0		
90.0		
626.421	758.046	
10.023	12.128	
1.659	2.008	
1.695		
7.6307	7.9545	
7.615	8.4827	The large amount of waste caused, doubtless, an over estimate of the coal on the grate at the end of the period of steady action.
8.1916	7.8645	
84°.19		
72°.76		
225°.86	239°.12	
267°.52	285°.80	With the air plate open, the gases arrived at the chimney 32° hotter than with that plate closed, as witnessed in a similar case, while trying the preceding sample.
229°.95		
81°.19		
30.034		
5.231		
0 5385		
0 227	0.2878	
68°.55		
141°.67	153°.96	
39°.18	55°.61	
7.6002	7.9217	
8 5565	8 9107	
479 27	493.28	
10 5922	10 7236	
1.4125	1.4235	
6 0921	6.2547	
Open.	–	From the 43d line, it should seem that a slight advantage in point of economy was derived from the use of the open air plate, as the 2d trial, in which that arrangement was adopted, gave a greater result in water to 1 of combustible, than had been obtained on the 1st trial.
U. 5		

No. 10.

Bituminous coal from Quin's run, Clinton county, Pennsylvania, sent for trial by Messrs. McDonald & Hullenback.

This sample of coal was accompanied by the following letter:

"Farrandsville Post Office,
"*Clinton county, Pa., Quin's run, August* 20, 1842.

"Some time since we shipped for your experiments at Washington four hogsheads of bituminous coal, marked 'Navy yard, D. C.,' to be transshipped at Columbia, Pennsylvania, to the seat of Government. We would thank you to instruct the proper persons having charge of the coals received for trial, to give attention to them, if not too late for the experiments.

"The coal marked No. 1 is different from the others, and we believe will be found a superior article.

"We have the honor to remain, gentlemen, very truly, your obedient servants,

"McDONALD & HALLENBACK.

"To the Navy Commissioners,
"*Washington, D. C.*"

The exterior characters of this coal are, a *color* almost uniformly shining jet black—except, of course, the faces marking the planes of deposition, in which the usual reedy matter, in the state of mineralized charcoal, gives a dull deep black, with numerous well-marked but small organic remains.

The main partings are well defined, and incline to the surfaces of deposition in angles of 85° and 95°. The cross partings are also, in many specimens, unusually well defined; smooth and brilliant plane surfaces, inclined to the main partings in angles of 88.5° and 91.5°, and to the surfaces of deposition in 70° and 110°. The coal thus separates into rhombic prisms.

Occasional specks of sulphuret of iron present themselves in the natural partings.

The specific gravity of one specimen of this coal was found to be 1.3225, that of another 1.3404; the mean of which gives the calculated weight of 1 cubic foot of solid coal equal to 83.22 pounds.

Nineteen trials in the charge box proved its average weight to be 50.335 pounds per cubic foot, or 0.6048 of its calculated weight.

The space for stowing 1 ton is 44.502 cubic feet. Of moisture, it contains, by the analytical operations, 0.646 and 0.557 per cent., as determined by two specimens. By trial in the steaming apparatus, the proportion of moisture was found to be 0.836 per cent.

One specimen examined for sulphur gave 0.1019 per cent. of that ingredient.

The volatile matter, other than moisture, was 17.791 and 17.071 for the two specimens above referred to; and the total volatile matter in two specimens examined by Doctor King was 17 for one, and 22 per cent. for the other. The average will not therefore be far from true, if assumed as 18.465.

Four incinerations of each of the first-mentioned specimens gave a mean of 6.51 per cent. of earthy matter for the one, and 7.57 for the other. Hence the composition is as follows:

	Specimen *a*.	Specimen *b*.
Moisture - - - - - - - - -	0.559	9.679
Other volatile matter - - - - - - -	17.791	17.071
Earthy matter - - - - - - - -	6.510	7.570
Fixed carbon - - - - - - - -	75.140	74.680
	100.	100.
Volatile to fixed combustible - - - - -	1 : 4.228	1 : 4.375

Besides the preceding analyses, a comparative trial was made on forty specimens; from each of which a fragment was taken, and a portion of the powder of the whole subjected to the usual steps for determining the constituents. This gave—

Of moisture - - - - - - - - - - - -	0.131
Of other volatile matter - - - - - - - - - -	18.676
Of earthy matter - - - - - - - - - -	7.750
Of fixed carbon - - - - - - - - - -	73.443
	100.

Volatile to fixed combustible 1 : 3.93.

The ashes are almost perfectly white, whether procured from the single specimens, or from the mixture just described.

In burning 1,883.25 pounds of this coal, the residue from the furnace consisted of 143.26 pounds of gray ashes, weighing 37.09 pounds per cubic foot, and 25 pounds of slaty matter and clinker, weighing 29.7 pounds per cubic foot. Hence, the former was 7.61, and the latter 1.327 per cent.; and the total waste 8.937 per cent. of the coal burned.

There were found in the ashes 7.577 per cent. of combustible residue, and in the clinker 9.512 per cent. Hence, the *absolute* waste from the *furnace* is 8.232 per cent. Six and three-fourths pounds of soot withdrawn from the *flues*, gave of volatile matter 16.03, carbon 35.32, and ashes 48.65 per cent.

The time required for the attainment of a uniform rate of evaporation is not precisely determined in the first experiment; but it was less than one hour. In the second it was but thirty minutes. Three-quarters of an hour is, therefore, a full allowance for this effect. The mean amount of coke left after each trial was 14.75 pounds.

A trial of specimen *a*, above analyzed, afforded, with oxide of lead, from 20 grains of coal 573.3 grains of lead, or 28.665 times its weight. Deducting the moisture and ashes found in that specimen, which amount to 7.069 parts, the lead to 1 of *combustible* is found to be 30.846.

Of the powdered coal from forty specimens, two trials by litharge were also made—each upon 10 grains of the mixture. The *first* gave 284.6, the *second* 285.5 grains of metallic lead. As the earthy matter and moisture are here 7.881 parts, the lead to 1 of combustible, by the first trial, is 30.894, and for the second 30.982. The mean of these three, viz: 30.907, may be assumed as the average reducing power of the combustible matter of this coal.

When tried in the chain shop, this coal was found eminently useful for that species of work. Sixty pounds of it were sufficient to make eleven links of a chain $1\frac{5}{8}$ inch in diameter. It gave but little cinder, and a flame of moderate length.

In the performance of ordinary smith work, to which it was applied in the anchor shop, the result was also highly satisfactory. It gave little cinder, a coke soft and yielding, and a form of fire abundantly hollow for all the purposes there required.

TABLE LXXXVIII.

First trial—upper damper* 8 *inches open; air plates closed;

Date.	Hour	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 1	5.00	68	64	116	142	77	148	71	30.03	0.354	7.01	0.10	-	-
	8.00	74	67	132	230	77	227	72	30.03	0.527	5.30	0.20	-	87.75
	8.15	7[illegible]5	66	133	239	77	229	72	30.03	0.543	5.14	0.30	-	-
	8.30	74	67	134	250	78	230	73	30.04	0.585	5.22	0.30	145	-
	9.00	76	67	139	276	78	231	75	30.04	0.550	5.07	0.30	512	89.75
	9.30	78	68	152	284	78	232	76	30 03	0.543	5.14	0.28	1003	-
	10.00	78	68	172	267	78	232	77	30.04	0.551	5.06	0.30	1487	108.25
	10.30	79	67	185	280	78	232	77	30.04	0.546	5.11	0.30	1895	-
	11.00	80	68	193	286	77	232	78	30.03	0.545	5.12	0.26	2287	102.25
	11.30	81	69	204	284	77	232	78	30.03	0.547	5.10	0.28	2698	-
	P. M.													
	0.00	81	67	213	286	77	231	78	30.02	0.541	5.16	0.30	3170	108 25
	0.30	80	67	220	291	77	231	78	30.02	0.537	5.20	0.30	3600	-
	1.00	81	68	232	287	77	232	78	30.01	0.545	5.12	0.32	3945	-
	2.05	78	67	250	273	77	231	78	30.00	0.543	5.14	0.34	4860	100.50
	2.30	81	68	253	296	77	231	78	30.00	0 531	5.26	0.26	5312	102.75
	3.15	82	68	258	288	78	231	78	29.98	0.541	5 16	0.31	6037	94.75
	3.45	82	69	264	278	78	232	79	29.98	0.533	5.24	0.30	6377	-
	4.15	83	70	268	284	78	231	79	29.97	0.531	5.26	0.30	6802	109.75
	4.45	81	69	268	287	78	230	78	29.97	0.531	5.26	0.28	7147	-
	5.30	82	69	281	262	78	230	79	29.97	0 527	5.30	0.22	7399	-
	6.00	81	68	280	252	78	229	79	29.97	0.514	5.43	0.18	7807	-
	A. M.													
Aug. 2	5.25	-	66	188	196	78	216	70	29.99	0.397	6.60	0.12	7817	-
	5.45	66	64	185	186	78	213	69	29.99	0.367	6.90	0.12	8136	-

The period of steady action this day is from 9*h.* a. m. to 4*h.* 15*m.* p. m = 7*h.* 15*m.*; coal supplied to grate, 726.5 lbs.; water to boiler in that time, 6,230 lbs.; water to 1 of coal, 8.575.

QUIN'S RUN COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	61.6	48	— 6	-	Cloudy; wind NE., light; commenced firing; water in boiler 0.55 inch below normal level.
8.00	63.4	58	+ 3	-	Wood consumed, 304.5 lbs; commenced charging with coal.
-	62.8	59 5	10	-	Steam blowing off; weather clearing up; sun shining.
-	63.4	60	20	1.536	
9.00	62.5	63	45	2.262	Clear; wind NE., light.
-	63.3	74	52	2.283	
9.53	63.3	94	35	2.561	Placed 28 lbs. of this coal in drying apparatus.
-	61.1	106	48	2.162	
11.00	62.4	113	54	2.077	Filled tank at 10*h.* 55*m.* a. m.
-	63.7	123	52	2.177	Fire in good action.
0.00	60.3	132	55	2.500	
-	60 7	140	60	2.278	
-	62.0	151	55	1.828	Commenced drawing gases from lower flue at 0*h.* 59*m.* p. m.; drew in 32 minutes 80 cubic inches, which gave water 0.46 grain, carbonic acid 4.22 grains, oxygen 9.1104 cubic inches; temperature 75°.
1.20	61.6	172	42	2.237	
2.10	62.0	172	65	2.873	
3 15	61.5	176	57	2.560	Filled tank at 2*h.* 45*m.* p. m.
-	63.2	182	46	1.801	
4.15	64.5	185	53	2 251	
-	63.7	187	57	1.828	Contents of ash pit thrown on grate.
-	63.2	199	32	0.890	
-	62.0	199	23	-	Water in boiler left at 0.4 inch above normal level; damper reduced to 3 inches.
-	-	-	—20		
-	62 7	119	—27	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - - -	11.00
Ashes - - - - - - - - - - - -	55.75
Ashes behind bridge - - - - - - - - - -	5.45
Total clinker and ashes - - - - - - - - - -	72.20
Deduct wood ashes - - - - - - - - - -	0.635
Total waste from coal - - - - - - - - - -	71.565
Coke - - - - - - - - - - - -	16.11

TABLE LXXXIX.—

Second trial—upper damper 8 inches open; air plates open;

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of coal supplied to grate at each time.
	h. m. A. M.													
Aug. 2	5.50	66	64	185	186	78	213	69	29.99	0.367	6 90	0.12	-	-
	6.45	67	64	160	243	78	230	69	30.0 0	0.527	5.30	0.21	-	100.25
	7.10	68	64.5	169	257	77	231	69	30.00	0.530	5.27	0.23	-	100.75
	7.45	71	66	177	289	77	231	70	30.00	0.532	5.25	0.25	486	-
	8.15	72	67	188	290	77	231	71	30.00	0.532	5.25	0.26	786	-
	8.45	74	68	198	300	75	232	72	30.01	0.541	5.16	0.27	1249	-
	9.15	76	70	209	288	75	232	74	30.01	0.546	5.11	0.32	1663	104.75
	9 45	78	70	215	303	75	232	75	30.02	0.543	5.14	0.30	2047	-
	10.15	81	70	226	304	75	232	76	30.02	0.535	5.22	0.30	2611	106.75
	10.45	82	70	234	304	75	232	77	30.02	0.545	5.12	0.30	2926	-
	11.15	81	68	243	300	76	232	78	30.02	0.530	5.27	0.28	3501	104.75
	11.45	83	70	252	300	76	232	79	30.02	0.537	5.20	0.30	3906	-
	P. M. 0.15	84	72	255	308	76	231	79	30.01	0.529	5.28	0.29	4317	95.00
	0.45	84	71	262	300	76	232	79	30.01	0.545	5.12	0.33	4719	-
	1.15	83	70	262	276	76	232	79.5	30.01	0.536	5.20	0.33	5269	99.50
	1.45	85	71	282	306	76	231	80	30.02	0.536	5.20	0.28	5671	-
	2.15	84	69	286	314	76	232	80	30 00	0.533	5.24	0.28	6081	95.25
	2.45	85	70	288	318	77	232	80	30.02	0.528	5.29	0.29	6501	94.75
	3.15	85	70	290	307	76	232	80	30.01	0.520	5.37	0.27	6961	-
	3.45	84	70	294	297	76	232	80	30.01	0.529	5.28	0.26	7386	-
	4.15	84	69	295	308	78	232	80	30.01	0.542	5.15	0.28	7713	107.00
	4.45	83	69	295	320	78	230	80	30.01	0.539	5.18	0.30	8114	-
	5.15	82	69	308	280	78	231	79	30.01	0.530	5.27	0.26	8344	-
	5.45	83	70	312	264	78	230	79	30.00	0.519	5.38	0.24	8639	-
Aug. 3	A. M. 5.00	68	65	210	204	78	222	72	30.09	0.433	6.22	0.15	8646	-
	5.30	68	65	206	204	78	217	71	30.09	0.390	6 66	0.12	9126	-

Period of steady action, from 9*h*. 5*m*. a. m. to 2*h*. 45*m*. p. m.=5*h*. 40*m*.; coal to grate for the same time, 596 pounds; water to boiler, 4,976 pounds; water to one of coal, 8.349.

QUIN'S RUN COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	62.7	119	—27	-	Commenced firing.
6.45	62.2	93	+18	-	Wood consumed, 97.5 pounds; commenced charging with coal.
7.10	62.4	101	26	-	Air plates opened; steam blowing off.
-	63.3	106	58	2.206	Wind NE., light; sun obscured.
-	64.4	116	59	1.589	
-	65.1	124	74	2.453	Filled tank at 8*h*. 20*m*. a. m.
9.05	67.3	133	56	2.193	
-	66.5	137	71	2.034	
10.10	65.3	145	72	2.988	The coal in drying apparatus weighs 27 pounds 12¼ oz.
-	64.9	152	72	1.669	
11.15	62.0	162	68	3.046	
-	64.5	169	68	2.146	Filled tank at 11*h*. 55*m*. a. m.
0.00	67.3	171	77	2.177	Commenced drawing gases from lower flue at 0*h*. 46*m*.; drew in 27 minutes 80 cubic inches, which gave water 0.65 grain, carbonic acid 4.38 grains, oxygen 12.44 cubic inches; temperature at bath, 80°.
-	65.7	178	68	2.129	
1.05	64.5	179	44	2.913	
-	65.4	197	75	2.129	Grate bars became a little deranged; took 6 or 7 minutes to restore them to order; during which time one fire door was open.
2.00	62.4	202	82	2.172	
2.45	63.7	203	86	2.225	
-	63.7	205	75	2.437	
-	64.1	210	65	2.251	Filled tank at 3*h*. 50*m*. p. m.
4.15	62.4	211	76	1.706	
-	62.8	212	90	2.124	Air plates closed, and contents of ash pit thrown on grate.
-	63.2	226	49	1.219	Damper reduced to 4 inches.
-	64.5	229	34	-	Water in boiler left at 0.6 inch above normal level.
-	63.2	142	—18	-	Water in boiler found at 0.9 inch below normal level.
-	63.2	138	—13	-	Water in boiler adjusted.

RESIDUA.

	Pounds
Clinker	14.00
Ashes	77.25
Ashes behind bridge	6.05
	97.30
Deduct wood ashes	0.299
Total waste from coal	97.001
Coke	13.99
Soot, (from two burnings)	6.75

TABLE XC.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (T. LXXXVIII.)	2d Trial. (Tab. LXXXIX.)
		August 1.	*August* 2.
1	Total duration of the experiment, in hours	24.75	23.667
2	Duration of steady action, in hours	7.25	5.667
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	9.0	10.0
7	Total weight of coal supplied to grate, in pounds	904.0	1008.75
8	Pounds of coal actually consumed	887.89	995.36
9	Pounds of coal withdrawn and separated after trial	16.11	13.39
10	Mean weight, in pounds, of one cubic foot of coal	50.222	50.4375
11	Pounds of coal supplied per hour, during steady action	100.2	105.18
12	Pounds of coal per square foot of grate surface, per hour	7.121	7.475
13	Total waste, ashes and clinker, from 100 pounds of coal	8.026	9.745
14	Pounds of clinker alone, from 100 pounds of coal	1.222	1.4023
15	Ratio of clinker to the total waste, per cent.	15.2143	14.3896
16	Total pounds of water supplied to the boiler	8136.0	9126.0
17	Mean temperature of water, in degrees Fahrenheit	77°.6	76°.1
18	Pounds of water supplied at the end of experiment, to restore level	319.0	487.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	41.0	63.0
20	Pounds of water evaporated per hour, during steady action	859.31	878.22
21	Cubic feet of water per hour, during steady action	13.749	14.05
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.276	2.326
23	Pounds of water per square foot, by a mean of several observations	2.276	2.329
24	Water evaporated by one of coal, from initial temp. (a) final result	9.117	9.105
25	Water evaporated by one of coal, from initial temp. (b) during steady action	8.575	8.349
26	Pounds of fuel evaporating one cubic foot of water	6.8553	6.8644
27	Mean temperature of air entering below ash pit, during steady pressure	79°.69	81°.0
28	Mean temperature of wet bulb thermom., during steady pressure	67°.94	69°.47
29	Mean temperature of air, on arriving at the grate	212°.81	250°.0
30	Mean temperature of gases, when arriving at the chimney	281°.06	302°.0
31	Mean temperature of steam in the boiler	231°.31	231°.68
32	Mean temperature of attached thermometer	77°.375	77°.34
33	Mean height of barometer, in inches	30.0125	30.012
34	Mean number of volumes of air in manometer	5.164	5.212
35	Mean height of mercury in manometer, in atmospheres	0.5406	0.5357
36	Mean height of water in syphon draught gauge, in inches	0.2961	0.2981
37	Mean temperature of dew point, by calculation	62°.45	64°.49
38	Mean gain of temperature by the air before reaching grate	133°.12	169°.0
39	Mean difference between steam and escaping gases	51°.07	71°.27
40	Water to one of coal, corrected for temperature of water in cistern	9.0856	9.0755
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	10.2711	10.2729
42	Pounds of water, from 212°, to one cubic foot of coal	515.84	518.12
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	11.1675	11 3822
44	Mean pressure, in atmospheres, above a vacuum	1.4258	1.413
45	Mean pressure, in pounds per square inch, above atmosphere	6.2883	6.0997
46	Condition of the air plates at the furnace bridge	Closed.	Open.
47	Inches opening of damper, (U. upper)	U. 8.	U. 8.

TABLES LXXXVIII, LXXXIX.

Quin's Run coal.

Averages.	Remarks.
14.75	
50.3297	
102.09	
7.289	
8.8855	
1.3122	The greater proportion of clinker is found at the second trial, when the combustion and evaporation were more rapid than on the preceding day.
14.802	
868.7655	
13.8996	
2.3001	
9.111	
8.462	There was probably more coal on the grate at the end than at the beginning of the period of steady action.
6.8598	
231°.405	
291°.53	It will often be observed that when the open air plate produces an evaporative effect, as indicated in the 41st and 43d lines, superior to what had been obtained by the closed air plate, the temperature of air entering the chimney was also found higher with the *open* than with the *closed* plate.
0.2971	
151°.66	
61°.17	
9.0805	
10.272	The coincidence of the two trials is very near; but the total waste on the second being greater than on the first trial, the efficiency of the unit of combustible (line 43) is not quite so great in the first as in the second experiment. The opening of the air plate appears to have favored slightly the increase of evaporative effect.
516 985	
11.2748	
1.4194	
6.194	

Remarks on the three preceding tables.

By a reference to the two tables of experiments, LXXXVIII and LXXXIX, it will be seen that the rate of supplying water to the boiler during the period of steady action was, in general, very regular; and that the uniformity of rate extended, on the second trial, to an hour before and an hour after the limits assumed for steady action. But it did not commence till some time after the second charge of coal was all upon the grate, nor continue so late as when the last charge was all on. This renders it necessary, for the purposes of calculation, to assume the times specified at the foot of the table, for the commencement and termination of steady action. The boiler, in fact, performed its office for 7½ hours on the second day, at almost exactly the same mean rate as during the 5¾ hours between the times of supplying the third and that of the ninth charge of coal. As all the times elapsed between consecutive sets of observations had the same length, (namely, half an hour,) the result of the single calculation for the whole time is, of course, identical with that of the mean of the separate calculations, as seen in the 22d and 23d lines of the table of deductions in the column of the first trial.

The 3d line of the last table shows that the grate was of the same size in both trials; the 11th, that the coal was supplied five per cent. more rapidly on the second than on the first; the 20th, that, on an average, 19 pounds more of water were evaporated per hour on the second; the 39th, that the gases escaped to the chimney with 20 degrees more of an excess above the steam in the boiler on the second than on the first trial; the 43d line proves that 0.11 of a pound more of water was evaporated by a pound of combustible matter of the coal on the second than on the first trial; and the 46th line shows that on the first trial the air plate was closed, and on the second it was open. The syphon showed the mean force of draught on the two days to be nearly identical. These facts appear to prove conclusively the advantage to this coal of air admitted at the bridge.

No. 11.

Bituminous coal from Karthaus, Clearfield county, Pennsylvania, sent by C. S. McCoy & Company.

This sample was accompanied by a letter, of which the following is a copy:

"KARTHAUS, *June* 22, 1842.

"GENTS: According to your advertisement, and at your request, we have forwarded on to your department the quantity of bituminous coal you have required for a sample, although at considerable expense to get it to your place at this season of the year.

"We consider it a pleasure in forwarding samples of our coal to any part of the United States, not fearing but it will far surpass your expectations.

"We do flatter ourselves to think, from the trials already made of our coal, to say that we have the best bituminous coal in the world. All we ask is a fair trial. The coal we sent you was put in four hogsheads, marked 'from C. S. McCoy & Co.'s sample coal.' Two hogsheads were from the Karthaus, and two from the Salt Lick banks. We don't consider that there is any difference in the coal, as they are only one mile from each other; both on the west branch of the Susquehanna river. The coal we sent you was taken from the mine last.

"We can deliver any quantity of the coal at Port Deposit in the spring of the year, or as long as our river keeps up, which sometimes lasts three months.

"If our coal should suit you, and we could agree upon the price, it would be necessary for us to know soon, as it will require a good deal of preparation to build arks, which would have to be done in part this summer and fall. From Port Deposit it could be delivered to any of the points on the coast you have designated in your advertisement.

"We can deliver our coal at port at about $7 50 for 2,000 pounds. Our coal always sells on the Susquehanna river from 3 to 5 cents a bushel more than any other bituminous coal. We would like to hear from you as soon as you make the trial.

"We refer you to General James Irvin, member of Congress from Centre county, Pennsylvania, who is personally acquainted with us and our coal. If you think it necessary, one of us could come into your place and make arrangements.

"Yours, with respect,

"C. S. McCOY & CO.
"per J. G. LEBO."

As to exterior characters, this coal has a columnar structure, parting with ease at the surfaces of deposition, to which the main partings are at right angles. The cross partings are not, in general, well defined. The color is a deep black, and the lustre dull or shining, according to the particular ply examined. The surfaces in the main partings exhibit frequent flakes of carbonate of lime. Sulphuret of iron is occasionally found efflorescing among the carbonaceous matter in the horizontal partings.

The specific gravity of two specimens was 1.2919 and 1.2753, respectively; from the mean of which, the calculated weight in the mine is 80.22 pounds per cubic foot.

Thirty-five trials in the charge box proved the average weight per cubic foot, in the state in which it was received, to be 52.542 pounds—the extremes being 49.375 and 56.625, of which the mean is 53 pounds, or 0.6549 of the calculated weight.

The space required for 1 ton is 42.634 cubic feet.

The moisture expelled from the two specimens above tried was found to be 0.77 for the first, and 0.952 for the second. This was effected by exposing the powder to a temperature of 216° for more than an hour in the apparatus seen at plate I, fig. 1.

By drying in the apparatus K, (Plate II, Fig. 1,) connected with the boiler at the navy yard, the loss on 28 pounds was 5¾ ounces, or 1.282 per cent.

The per centage of volatile matter, other than moisture, was found, by rapidly coking the first specimen, to be 21.5 per cent.; and by coking so slowly as to prevent agglutination of the particles of coal, it was but 13.06 per cent. The second specimen gave, by a mean of two trials, both performed rapidly, 11.881 per cent.

Dr. King obtained from two specimens a mean of 23.25 per cent, of volatile matter. The mean of trials on four specimens gives the total volatile matter 19.23 per cent. Hence it appears that the Karthaus coal is superior in the amount of its volatile constituents to any of the free-burning coals hitherto examined. But its principal constituent is still the *fixed carbon*, which, for the least amount of volatile matter obtained by slowly coking the first specimen, was $\frac{80.999}{13.06}=6.124$ times as much as the latter ingredient; but by rapid coking, the ratio was reduced to $\frac{72.643}{21.5}=3.378$.

The incineration of each specimen was made in the same manner as of other samples. Specimen *a* gave 5.087, and specimen *b*, 6.68 per cent. of reddish-gray ashes.

In one hundred parts, therefore, there were in

	Specimen *a*.	Specimen *b*.
Water - - - - -	0.770	0.952
Other volatile matter - - -	21.500	11.881
Earthy matter - - - -	5.087	6.680
Carbon - - - - -	72.643	80.487
	100.	100.
Volatile to fixed combustible -	1 : 3.378	1 : 6.812

During the four trials on evaporation, the total weight of coal burned was 3,643.84 pounds, which produced of clinker 136.71 pounds, and of ashes 133.73.

The ashes, by complete reincineration, lost 12.6 of their weight, and the clinker was reduced to 2.13 per cent. by the same means; so that the absolute amount of waste withdrawn from the *furnace* was 255.05 pounds; of which the part in the state of clinker was 52.46 per cent., and the whole was 7 per cent. of the coal consumed. The ashes weigh 47.94 pounds per cubic foot, and are, when completely freed from carbon, of a light reddish-gray color. The clinker weighs 32.75 pounds per cubic foot, and is of a dark-brown and iron-black color, with yellowish shaly portions. It is in small fragments, porous in texture, and not so much agglutinated as to cause very serious obstruction to the passage of air.

The large proportion of clinker is in part accounted for by the presence of sulphuret of iron in such quantity as to yield 1.58 per cent. of sulphur from the specimen *a*, above analyzed.

The accendibility of this coal (that is, the degree of readiness with which its combustion commences) is indicated by the fact that it required on an average 1¼ hour to bring the boiler into steady action after the charging with coal had commenced.

The weight of coke withdrawn after each trial was, on an average, 8.578 pounds.

A trial of specimen *a* by the oxide of lead resulted in reducing 31.328 times its weight of metallic lead; and this, deducting the incombustible materials present, gives for 1 of combustible, 33.309.

This coal was tried for its general adaptation to smithing purposes, both in the chain and anchor shops, where it was found to give a good hollow fire, preserving the arch without danger of disturbance from the blast, and to produce a clear and effective welding heat. The coke is not quite equal for sustaining a good durable fire to that from some other coals of the free-burning class.

In a well-set office grate, with a good draught, it was found to require considerable time for ignition, kindling slowly at the bottom. More than an hour elapsed before any considerable activity of combustion had been attained. While any of the vaporizable and gasefiable ingredients of coal remain, the mass will remain mostly black. White or yellowish vapors continue to be given off at the top of the mass; and even if temporarily ignited, by bringing any flaming body in contact with these gaseous materials, they will generally burn but fitfully, and their inflammation will last no longer than the torch with which they are attempted to be ignited is kept in contact with the issuing current of mixed vapors and gases. It will be seen, on consulting the tables of experiments with that of deductions following them, that some difference in evaporative power was observed while using different casks of the sample; but, as the two localities from which they came were not designated, the whole is, of course, taken as a single sample.

In coking rapidly, this coal discharges gas copiously, intumesces strongly, forming a coherent porous mass, moderately tough, and of a steel-gray color. By coking more slowly, the consistence is more compact and tough; and by very slow treatment, the powder is scarcely rendered in any degree coherent. The coke of this coal is well adapted for smelting iron.

TABLE XCI.—

First trial—upper damper 12

Date.	Hour.	TEMPERATURES OF THE							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m.													
	A. M.													
April 6	6.00	40	-	90	100	42	172	-	29.97	-	-	0.10	-	-
	7.00	40	-	82	174	42	192	-	29.97	-	-	0.10	-	-
	8.30	44	-	94	214	42	226	-	29.97	-	-	0.15	-	-
	8.45	44	-	96	194	42	226	-	29.97	-	-	0.15	-	104.00
	9.00	44	-	104	196	42	224	-	29.97	0.118	9.40	0.12	-	100.50
	10.00	46.5	-	108	212	44	228	-	29.97	0.145	9.15	0.26	-	-
	10.10	47	-	110	226	44	228	-	29.96	0.140	9.08	0.27	70	108.50
	10.45	48	-	118	242	48	228	-	29.97	0.160	9.00	0.28	410	-
	11.45	48	-	132	280	56	230	-	29.97	0.170	8.88	0.30	900	-
	P. M.													
	0.25	49	-	152	254	66	229	-	29.96	0.166	8.92	0.30	1400	-
	1.04	50	-	170	292	88	230	-	29.96	0.180	8.78	0.30	2010	-
	1.25	50.5	-	184	254	97	229	-	29.96	0.163	8.98	0.30	2310	-
	1.45	51	-	204	230	60	229	-	29.96	0.153	8.05	0.25	2310	107.75
	3.25	51	-	226	236	62	230	-	29.96	0.166	8.94	0.30	3500	217.25
	4.00	51	-	234	284	62	230	-	29.96	0.170	8.90	0.30	4184	-
	4.15	50.5	-	238	272	62	230	-	29.96	0.173	8.87	0.31	4443	104.00
	5.05	51	-	248	276	62	230.5	-	29.96	0.180	8.78	0.31	5217	105.00
	5.40	51	-	255	288	62.5	229.75	-	29.96	0.173	8.86	0.31	5628	102.50
	6.10	52	-	270	280	62.5	229	-	29.96	0.165	8.94	0.30	6460	-
	A. M.													
April 7	6.15	42	-	150	170	64	204	-	30.10	-	-	0.12	7250	-

The period of steady action is from 10*h.* 10*m.* a. m. to 5*h.* 40*m.* p. m. = 7*h.* 30*m.*; coal supplied to grate, 636.5 lbs.; water to boiler; 5,558 lbs.; water to 1 of coal, 8.732. This being the first experiment of the series, less regularity in the supplying both of coal and of water is observable, than were found practicable after a little training and experience on the part of the firemen and other assistants.

KARTHAUS COAL.

inches open; no air plate used.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.625 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					Manometer contains 10.911 volumes of air.
-	-	50	—72	-	Commenced firing.
-	-	42	—18	-	Wood consumed, 266 lbs.; ashes of wood withdrawn; commenced charging with coal.
-	-	50	—12		
8.45	-	52	—32		
9.00	-	64	—28		
-	-	61.5	—16		(No observations on the wet bulb thermometer were taken,
10.10	-	69	— 2	1.112	and of course no dew points were computed.)
....	....	....	....	....	
-	-	70	+14	1.543	
-	-	84	50	1.298	The upper stopcock of the supplying apparatus leaking slightly, allows a small quantity of steam to get to, and
-	-	103	25	2.225	raise the temperature of, the water in cistern.
-	-	120	62	2.241	
-	-	139.5	25	2.271	Damper nearly closed; upper stopcock of supplying appa-
1.45	-	153	1	1.576	ratus tightened; filled tank.
3.25	-	175	6	1.576	In the *weight of charges*, two boxes are included for this
-	-	183	54	3.105	hour.
4.15	-	187.5	42	2.744	
5.05	-	197	45.5	2.461	
5.40	-	204	58.25	1.863	The coal of this experiment is nearly all fine or slaked.
....		....	....	....	
-	-	218	51		
		....			
-	-	108	—34	-	Water adjusted in boiler.

RESIDUA.

	Pounds.
Clinker	33.12
Ashes	17.00
Total waste from coal	50.12
Coke	9.8

TABLE XCII.—

Second trial—upper damper

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
April 7	8.50	44	-	150	158	43	194	-	30.13	-	-	0.12	-	-
	10.15	50	-	140	244	43	224	-	30.12	0.140	9.18	0.16	-	102.75
	10.45	50.7	-	142	244	43	228	-	30.12	0.175	8.85	0.20	-	110.75
	P. M. 0.00	52.5	-	170	294	43.5	230	-	30.12	0.195	8.64	0.26	910	107.25
	0.48	53.5	-	200	324	44	230.5	-	30.11	0.195	8.64	0.28	1890	113.25
	1.30	55	-	244	312	44	230.5	-	30.08	0.195	8.64	0.28	2705	113.25
	3.00	57	-	310	308	44	230	-	30.08	0.196	8.62	0.29	4015	219.15
	3.45	57.5	-	328	306	51	230.5	-	30.07	0.193	8.65	0.29	4765	106.75
	4.40	58	-	340	311	51	230	-	30.07	0.185	8.74	0.30	5685	105.00
	5.30	59	-	346	304	51	230.5	-	30.02	0.186	8.72	0.30	6517	112.50
	6.00	59.5	-	352	330	51	230	-	30.02	0.178	8.81	0.28	7300	-
April 8	A. M. 6.00	50	-	162	180	52	205	-	29.79	-	-	0.13	8335	-

Period of steady action, from 12*h.* m. to 5*h.* 30*m.* p. m. = 5*h.* 30*m.*; coal supplied to grate, 769.9 lbs.; water to boiler, 5,607 lbs.; water to 1 of coal, 6.581. The coal appears to have been supplied more rapidly than it was consumed, leaving a heavy bed on the grate, to perform its office during the night.

KARTHAUS COAL.

12 *inches open; air plates open.*

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.625 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet; a perforated plate for the admission of air introduced at back of grate.
h. m.					
-	-	106	—36	-	Commenced firing; filled tank.
10.15	-	90	+20	-	Wood consumed, 190.5 lbs.; commenced charging with coal.
10.45	-	91.3	16	-	Two rows of holes opened in air plates.
0.00	-	117.5	64	1.928	Four rows of holes opened in air plates; no smoke from chimney.
0.48	-	146.5	93.5	3.245	
1.30	-	189	81.5	3.083	
3.00	-	258	78	2.318	Filled tank.
3.45	-	270.5	75.5	2.649	
4.40	-	282	81	2.658	Air plate entirely opened.
5.30	-	287	73.5	2.644	The coal consumed this day contains more lumps than that burned in the first experiment.
-	-	292.5	100	-	Contents of ash pit thrown on grate; water in boiler 1.5 inch above normal level.
-	-	112	—25	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	49.75
Ashes	27.25
	77,00
Deduct wood ashes	0.585
Total waste from coal	76.415
Coke	4.375

TABLE XCIII.—

Third trial—upper damper 12 inches

The period of steady action extends from 10*h.* a. m. to 5*h.* 30*m.* p. m. = 7*h.* 30*m.*; coal supplied to grate, 707.5 lbs.; water to boiler, 5,655 lbs.; water to 1 of coal, 7.992.

KARTHAUS COAL.

open; air plates 7 holes open.

Time each charge was on grate.	Dew point, by calculation.				
h. m.					
-	-	96	—36	-	Commenced firing.
7.56	-	90	+ 0	-	Wood consumed, 187.5 lbs.; steam blowing off; commenced charging with coal.
-	-	93	8		
9.00	-	107	24	1.013	
10.00	-	124	21	[illegible]	
11.00	-	157	36	2.106	
0.00	-	199.5	[illegible]	1.867	
1.00	-	242	29	2.305	Fire active.
2.00	-	262	25	1.748	
3.15	-	271	11	0.596	Scarcely any smoke seen at chimney top; tank empty.
-	-	282	22	2.054	Tank partly filled; water in river too low to be reached.
4.20	-	280	47	1.695	Filled tank, the tide being now partially up.
5.30	-	304	40	2.869	Coal of this day's experiment fine or slaked.
-	-	301.5	36	1.351	
-	-	397.5	22		
-	-	[illegible]	—14		
-	-	136	—17	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	34.094
Ashes	36.979
Ashes behind bridge	9.370
Total clinker and ashes	80.443
Deduct wood ashes	[illegible]
Total waste from coal	79.867
Coke	9.937

TABLE XCIV.—

Fourth trial—upper damper

Period of steady action computed from 9*h*. 20*m*. a. m. to 2*h*. p. m.—5*h*. 40*m*.; coal supplied to grate, 416.75 lbs.; water to boiler, 3,435 lbs.; water to 1 of coal, 8.242.

KARTHAUS COAL.

12 inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.89 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	126	—17	-	Commenced firing.
8.20	-	118	+18	-	Wood consumed, 171.5 lbs; commenced charging with coal; steam at equilibrio.
-	-	124	40	-	Steam blowing off.
9.20	-	138	45	1.271	
-	-	172	51	1.783	Filled tank.
11.05	-	215	38	1.759	
0.15	-	227	46	1.165	Fire sluggish.
-	-	236	39	1.880	
-	-	247	50	1.668	
2.00	-	260	49	2.246	
-	-	270	51	2.204	
3.00	-	278	37	1.112	Coal consumed to-day, a mixture of lumps and fine.
-	-	288	43	1.773	Ash pit contents thrown on grate.
-	-	307	21	2.172	
-	-	301	3	0.523	
-	-	144	—24		
-	-	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	19.75
Ashes	45.00
Ashes behind bridge	5.63
Total clinker and ashes	70.38
Deduct wood ashes	0.526
Total waste from coal	69.854
Coke	10.50
Soot and dust	15.00

TABLE XCV.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (*Tab. XCI.*)	2d Trial. (*Tab. XCII.*)
		April 6.	*April* 7.
1	Total duration of the experiment, in hours	24.25	21.166
2	Duration of steady action, in hours	7.5	5.5
3	Area of grate, in square feet	14.625	14.625
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	19.485	19.485
6	Number of charges of coal supplied to grate	9.0	10.0
7	Total weight of coal supplied to grate, in pounds	949.5	1090.65
8	Pounds of coal actually consumed	940.0	1086.28
9	Pounds of coal withdrawn and separated after trial	9.5	4.375
10	Mean weight, in pounds, of one cubic foot of coal	52.75	54.5225
11	Pounds of coal supplied per hour, during steady action	84.867	139.98
12	Pounds of coal per square foot of grate surface, per hour	5.803	9.571
13	Total waste, ashes and clinker, from 100 pounds of coal	5.2451	7.0345
14	Pounds of clinker alone, from 100 pounds of coal	3.532	4.5439
15	Ratio of clinker to the total waste, per cent.	66.488	64.595
16	Total pounds of water supplied to the boiler	7250.0	8335.0
17	Mean temperature of water, in degrees Fahrenheit	55°.6	47°.6
18	Pounds of water supplied at the end of experiment, to restore level	790.0	1025.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	111.0	153.0
20	Pounds of water evaporated per hour, during steady action	741.07	1019.45
21	Cubic feet of water per hour, during steady action	11.857	16.31
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.9629	2.7005
23	Pounds of water per square foot, by a mean of several observations	2.0821	2.765
24	Water evaporated by one of coal, from initial temperature (a) final result	7.5947	7.5321
25	Water evaporated by one of coal, from initial temperature (b) during steady action	8.7321	6.5813
26	Pounds of fuel evaporating one cubic foot of water	8.2294	8.2978
27	Mean temperature of air entering below ash pit, during steady pressure	50°.25	56°.5
28	Mean temp. of wet bulb thermometer, during steady pressure	–	–
29	Mean temperature of air, on arriving at the grate	202°.58	286°.25
30	Mean temperature of gases, when arriving at the chimney	267°.33	311°.125
31	Mean temperature of steam in the boiler	229°.52	230°.25
32	Mean temperature of attached thermometer	47°.0	54°.0
33	Mean height of barometer, in inches	29.962	30.071
34	Mean number of volumes of air in manometer	8.9083	8.6826
35	Mean height of mercury in manometer	0.1682	0.1910
36	Mean height of water in syphon draught gauge, in inches	0.2963	0.290
37	Mean temperature of dew point, by calculation.		
38	Mean gain of temperature by the air, before reaching grate	152°.33	229°.75
39	Mean difference between steam and escaping gases	37°.81	80°.875
40	Water to one of coal, corrected for temp. of water in cistern	7.5947	7.5321
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	8.7479	8.7343
42	Pounds of water, from 212°, to one cubic foot of coal	461.45	476.6
43	Water, from 212°, to one pound of combustible matter of the fuel	9.2322	9.3952
44	Mean pressure, in atmospheres, above a vacuum	1.4151	1.426
45	Mean pressure, in pounds per square inch, above atmosphere	6.1299	6.291
46	Condition of the air plates at the furnace bridge	(None in.)	Open.
47	Inches opening of damper, (U. upper)	U. 12	U. 12

TABLES XCI, XCII, XCIII, XCIV.

Karthaus coal.

3d Trial. (*Tab. XCIII.*)	4th Trial. (*Tab. XCIV.*)	Averages.	Remarks.
April 28.	*April* 29.		
24.25	24.0		
7.5	5.667		
14.89	14.89		
377.5	377.5		
19.85	19.85		The grate at the 1st trial was 12 inches in front and 14 inches at the rear, below the bottom of the boiler; on the 2d trial it was 1 foot below; on the 3d and 4th, 9 inches below.
10.0	6.0		
1009.75	628,25		
999.81	617.75		
9.94	10.5	8.578	On the 2d trial, a cask of the sample was used which contained a larger proportion of lumps than the first, as will be noticed in the remarks in table XCII; hence its superior weight per cubic foot. There were also more lumps in the 4th than in the 3d day's burning, with a corresponding superiority of weight per cubic foot.
50.4875	52.3542	52.531	
94.33	73.553	98.1825	
6.335	4.939	6.662	
7.988	11.308	7.8939	
3.3866	3.1728	3.6588	
42.392	28.059	50.3835	
8060.0	5375.0		
68°.4	68°.4		
645.0	400.0		
87.0	53.0		
754.0	606.248	780.192	
12.06	9.699	12.4815	
1.997	1.606	2.0666	
1.980	1.676		
7.9745	8.6151	7.9291	
7.992	8.242	7.8868	
7.8375	7.2547	7.9048	
69°.09	75°.1		
–	–	–	This being the first sample of coal tried, no observations for dew point were taken, as the apparatus had not, at the time, been completed.
296°.36	291°.8	269°.2475	
258°.27	273°.1	277°.456	
229°.18	238°.5		
67°.0	72°.0		
30.055	30.054		
8.7682	8.857		
0.182	0.174		
0.165	0.1544	0.2264	The syphon tube was rather too small to be duly sensible, and it was found necessary frequently to renew the colored water, owing to a slight tendency to viscidity, caused by the coloring material—cochineal. A tube four or five tenths of an inch in diameter, afterwards employed, obviated this difficulty.
227°.27	216°.7	206°.5125	
29°.09	44°.6	48°.094	
7.9739	8.5982	7.9247	
9.0856	9.797	9.0912	As there were two varieties of coal in this sample, so there are two sets of results, as obvious in this line. The 1st and 2d trials appear to belong to one variety, and the 3d and 4th to another. As no marks were found to distinguish the coal of one locality from that of another, the whole is, of necessity, taken as one sample.
458.71	512.91	477.4175	
9.8744	11.0461	9.887	
1.4366	1.4279	1.4264	
6.4474	6.3198	6.297	
Open (7 rows.)	Fully open.		
U. 12	U. 12		

ish-white shaly portions adhering to such as are more fully vitrified. It is cemented into large porous masses.

The soot collected from the flues after burning this coal weighed but 7.83 pounds per cubic foot, and lost by complete incineration 55.86 per cent., leaving of course 44.14 per cent. of reddish-gray ashes. The total weight of soot was not exactly ascertained. The quantity was moderate.

The effect of the clinker from this coal in impeding the draught, and rendering the combustion irregular, will be understood from an inspection of the tables of combustion, in which wide differences will be observed between the evaporation at one period and that at another. The large proportion of clinker to the total waste might lead us to expect that much

reduced. This is confirmed by an experiment

ed, which gave 1.5 per cent. of sulphur.

y oxide of lead resulted in giving 28.127 times

, deducting the moisture and earthy matter, it

power of the unit of combustible matter in this

e described afford the following composition for

	Specimen *a*.	Specimen *b*.
Moisture - - - - -	0.700	1.105
Sulphur - - - - -	1.500	(not tried.)
Other volatile matter - - -	18.195	20.255
Ashes - - - - -	15.360	9.050
Fixed carbon - - - -	64.245	69.590
	100.	100.
Fixed to volatile combustible -	3.535 : 1	3.435 : 1

Treated with scale oxide of copper, 7.26 grains of specimen *a*, well dried, afforded of carbonic acid 20.62 grains, equivalent to 5.6236 grains of carbon; and 3.23 grains of water, equivalent to 0.3588 grain of hydrogen. The ashes are 15.762 per cent. of the dried coal, or 1.1444 grain, leaving for oxygen and azote 0.1332 grain. Hence the combustible matter alone is 6.1156 grains; and, excluding the earthy matter, the several constituents have to each other the following relations, viz:

Carbon - - - - - -	91.955
Hydrogen - - - - - -	5.867
Oxygen and azote - - - - -	2.178
	100.

Of this *combustible matter*, if the *heating* power be computed from that of its carbon alone, it amounts to $0.91955 \times 12906 = 11868$; and the *evaporative* power to $11868 \div 1030 = 11.522$.

The table of deductions shows that the evaporative power of 1 of combustible matter, as applied to the boiler, was, on an average, 10.238. If this number be increased by adding the heat expended on the air which supplied the furnace, the moisture of that air and the water generated in combustion, and which was proved in the case of a coal of analogous properties (that from Quin's run) to have been 12.823 per cent. as much

as was absorbed by the boiler, then will the *evaporative power* of the unit of combustible matter be represented by - - 11.550
While, as above, that of the carbon is - - 11.522

Difference - - - - 0.028=$\frac{1}{411}$th part.

This coal was tried, under my direction, both in the chain cable and the anchor shops, being, by the kindness of the master blacksmith, (Mr. Tucker,) placed in each shop in the hands of one of the most skilful and expert workmen.

It was found to come rapidly into combustion, and to afford an intense heat. A large bolt, which had just before been brought to a good working heat by coal in ordinary use in the yard, was by that now under consideration brought to the same degree of heat in ten minutes less time. The compactness of the coking mass appeared to be sufficient to form a good hollow fire for work of the size now performed by it. The cinder taken out was stated to be far less than that given by coal in common use at that time. The workman stated that he had been working in the yard for six years, and that this was the best coal, for the work he was then engaged on, which he had used in all that time. Two other workmen tried each a small portion of it, and both commended it very highly.

The smoke, while using this coal, was observed to be far less than that from any of the other fires (of which some ten or a dozen were in action) using the ordinary coal of the yard. The only fault is the lightness of the coke, which requires the fire to be frequently "wetted down."

In the chain shop, the workmen spoke of the same inconvenience from lightness of the coke. But on a small chain it was found to work well, giving very promptly a good welding heat, without interference from foreign matter. The cinder was stated to be about half as much as would be obtained in the same time from the coal now in general use, (the Midlothian.) Freedom from smoke was here remarked upon with approbation by the workmen, and was very conspicuous among the large number of smoky fires then in use at the same shop.

The amount of volatile matter in this coal is too small to commend it for use in procuring illuminating gas.

For domestic purposes, it may be employed in open grates with great advantage, on account of the clear combustion of its gaseous products.

The accendibility of this coal does not appear to be equal to that of some of the other free-burning class—it having required two hours, on an average of the four trials, to bring the boiler into steady action. By a like average, it also appears that there were withdrawn from the grate, after combustion had ceased, 14.812 pounds of unburnt coke.

In the table of deductions, following those of the experiments on evaporation, it will be observed, that though the weights of coal actually consumed at the several trials were very different, (being in one case 1,271.25, and in another only 331.25 pounds,) yet that the evaporative effects of the pound of coal are all very near each other; a circumstance which indicates the reliance to be placed on the method of determining the relative heating powers of fuel adopted in this research. Though all fine, it was observed to form a slightly coherent coke, which, on being broken up with the slice iron, allows a free passage to the air, and favors a brisk combustion.

TABLE XCVI.—CAMBRIA COUN

First trial—upper damper 8 inches

Period of steady evaporation, from 11h. 30m. a. m. to 6h. 45m. p. m. = 7h. 15m. Coal supplied to grate, 740.75 lbs.; water to boiler, 5,400 lbs.; water to 1 of coal, 7.290.

TY (PENNSYLVANIA) COAL.

open; air plates removed.

		Gain of temperature by the air before reaching grate.	Difference of temperature between steam & escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	134.5	—16	-	Water in boiler adjusted.
-	-	134.5	—16	-	Commenced firing; filled tank at 7*h*. 45*m*. a. m.
-	-	139	+39	-	Wood consumed, 350.25 lbs.; commenced charging with coal; steam at equilibrium.
-	-	136.5	39	-	Steam blows off.
9.20	-	132.5	47		
10.16	-	138	84	0.446	Damper set 8 inches.
-	-	165	86	1.077	
11 30	-	186	98	1.695	
-	-	204	76	2 198	
0.25	-	222	57	3.147	
1.00	-	243	74	2.679	
-	-	244	60	1.351	
2.30	-	250	78	0.540	
-	-	251	74	2 496	
3.50	-	269	38	2.281	Filled tank at 4*h*. 15*m*. p. m.
4 45	-	276.5	44	1.179	
-	-	271	61	0.749	
5.50	-	277	59	3.046	
-	-	279	86	2.002	
6.45	-	279	69	3.867	
-	-	-	-	-	Closed air port, and nearly closed damper.
-	-	190	—30	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	49.75
Ashes	53.50
Ashes behind bridge	3.00
	106.25
Deduct wood ashes	0.768
Total waste from coal	104.482
Coke	18.50

TABLE XCVII.—CAMBRIA COUN

Second trial—upper damper 12 inches

Period of steady action, from 2*h*. 45*m*., when the 4th charge had all been placed on the grate, to 6*h*. 35*m*. p. m., when the 8th and last charge was all on = 3*h*. 50*m*.; coal supplied to grate 405.25 lbs; water to boiler, 4,020 lbs.; water to 1 of coal, 9.919.

TY (PENNSYLVANIA) COAL.

open; air plates 7 rows open.

Time each charge was on grate.					
h. m.					
-	- -	29	—16	-	Commenced firing; filled tank at 8*h.* 40*m.* a. m.
-	- -	101	+ 4	-	Wood consumed, 455.75 lbs.; steam at equilibrium; commenced charging with coal.
-	-	103	10	-	Steam blowing off; air plates opened.
11.35	-	98	33		
0.10	-	[illegible]	34	[illegible]	
1.10	-	173	[illegible]	1.142	
2.45	-	198	21	1.774	
-	-	209.5	27	3.743	28 lbs. of this coal, after remaining in the drying apparatus 24 hours, weighed 27 lbs. 12¾ oz.
[illegible]	-	226.5	33	2.295	
5.00	-	230.5	41	3.867	Filled tank.
5.60	-	258	30	0.984	The 7th and 8th charges contain some of the coke left from 1st trial, which accounts for their less weight than that of the other charges.
6.25	-	260.5	44	2.765	
-	-	267	34	-	No smoke (except when charging and stoking) visible at chimney top.
-	-	139	—44		
-	-	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	28.00
Ashes	49.70
Ashes behind bridge	2.08
	79.78
Deduct wood ashes	1.40
Total waste from coal	78.38
Coke	10.00

TABLE XCVIII.—CAMBRIA COUN

Third trial—upper damper 12 inches

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Apr. 25	7.30	62	-	184	240	68	205	-	29.95	-	-	-	-	-
	8.45	65	-	188	210	68	226	-	29.95	0.159	9.00	0.20	-	-
	9.00	66	-	188	244	68	226	-	29.95	0.173	8.86	0.20	-	105.25
	9.45	68	-	182	266	68	228	-	29.97	0.183	8.76	0.20	155	-
	10.15	70	-	202	264	68	229	-	29.95	0.183	8.76	0.20	475	107.75
	11.00	70	-	234	274	68	229	-	29.94	0.173	8.80	0.20	1055	-
	11.25	70	-	254	278	68	229	-	29.94	0.176	8.82	0.20	1455	108.00
	11.45	70	-	262	272	66	229	-	29.92	0.178	8.82	0.20	1795	-
	P. M. 0.35	70.5	-	286	258	70	229	-	29.91	0.179	8.80	0.20	2215	103.25
	1.10	71	-	298	274	70	230	-	29.91	0.176	8.82	0.20	2665	-
	1.45	71	-	304	270	71	229	-	29.90	0.180	8.78	0.18	2665	104.25
	2.30	72	-	326	272	71	229	-	29.89	0.177	8.82	0.18	3485	-
	3.00	73	-	340	270	72	229	-	29.89	0.173	8.86	0.18	3900	102.00
	3.30	73	-	352	262	71	229	-	29.89	0.170	8.88	0.20	4325	-
	4.00	73	-	378	252	71	229	-	29.89	0.173	8.86	0.20	4325	112.00
	4.30	74	-	382	258	71	229	-	29.88	0.170	8.89	0.18	4570	-
	5.00	76	-	368	268	72	229	-	29.88	0.170	8.89	0.20	5330	106.50
	5.30	74	-	378	254	70	230	-	29.88	0.173	8.86	0.20	5585	-
	6.00	73	-	390	268	69	230	-	29.88	0.175	8.84	0.20	5585	-
	6.40	70	-	400	272	68	229	-	29.86	0.175	8.84	0.20	6185	102.00
	7.20	69	-	406	284	70	230	-	29.86	0.180	8.80	0.22	6185	-
	7.50	69	-	416	276	70	229.5	-	29.86	0.169	8.91	0.21	6435	106.50
	8.20	69.5	-	422	292	70	230	-	29.86	0.177	8.82	0.20	6765	-
	8.50	69	-	434	282	70	229.5	-	29.87	0.175	8.84	0.20	7495	-
	9.20	69	-	440	284	70	229.5	-	29.89	0.177	8.82	0.21	8147	106.50
	9.50	69	-	434	296	70	230	-	29.90	0.177	8.82	0.20	8395	-
	10.30	68	-	428	287	70.5	230	-	29.92	0.177	8.82	0.21	8873	113.25
Apr. 26	A. M. 5.30	60	-	280	212	71	200	-	29.90	0.140	9.12	0.12	10480	-

Period of steady action, from 11*h.* 25*m.* a. m. to 10*h.* 30*m.* p. m. = 11*h.* 5*m.*; coal supplied to grate in that time, 968.25 lbs.; water to boiler, 7,418 lbs.; water to 1 of coal, 7.661.

TY (PENNSYLVANIA) COAL.

open ; air plates 7 rows open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.89 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	122	— 5	-	Commenced firing.
-	-	123	+34	-	Wood consumed, 193.5 lbs.; steam at equilibrium; commenced charging with coal; temperature of gas in chimney taken at lower flue at this set; steam blows off at 9*h*., when the lower damper was closed, and the upper one opened at 12 inches; air plates also opened.
8.45	-	122	18		
-	-	114	38	0.573	
10.15	-	132	35	1.695	
-	-	164	45	1.695	
11.25	-	184	49	2.543	
-	-	192	48	2.702	Tank partly filled.
0.35	-	215.5	29	1.395	
-	-	227	44	2.049	
1.45	-	233	41	-	Filled tank.
-	-	254	43	1.629	
3.00	-	267	41	2.198	
-	-	279	38	-	The coal in drying apparatus weighs 27 lbs. 5 oz.
4.00	-	305	23	1.125	
-	-	308	29	0.649	
5.00	-	292	39	4.026	
-	-	304	24	1.351	Filled tank.
-	-	317	38		
6.20	-	330	48		
-	-	337	54	0.867	
7.50	-	347	46.5	1.824	
-	-	352.5	62	1.748	
-	-	365	52.5	3.867	
9.00	-	371	54.5	3.464	
-	-	365	66	1.312	
10.30	-	360	57	1.900	
-	-	220	12	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	50.25
Ashes	59.50
Ashes behind bridge	3.23
Total clinker and ashes	112.98
Deduct wood ashes	0.594
Total waste from coal	112.386
Coke	18.00

TABLE XCIX.—CAMBRIA COUN

Fourth trial—upper damper 3 inches open; air plates closed;

Period of steady action, from 2*h*. 15*m*. p. m. to 5*h*. p. m.—2*h*. 45*m*.; coal supplied to grate, 218 lbs.; water to boiler, 1,860 lbs.; water to 1 of coal, 8.527.

This computation of the period of steady action is, however, liable to some uncertainty, from the small amount of coal left for this experiment, and the consequent shortness of time allotted to the trial.

TY (PENNSYLVANIA) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	29.7	88	—37	-	Commenced firing; small furnace in action; filled tank.
0.45	33.3	94	—15	-	Wood consumed, 198 lbs.; commenced charging with coal; wind SE., light.
-	33.8	91	+ 4	0.439	Damper set at 8 inches at 1*h.* 15*m.* p. m.; steam escaped at 0*h.* 53*m.* p. m.
-	36.6	94	11	2.214	Smoke appears at chimney top, of a brownish color, for about 1½ minute after stoking.
2.15	34.8	99	32	0.619	
-	33.3	104	46	2.193	
-	35.1	112	37	1.684	
3.36	35.1	120	41	1.324	
3.55	35.1	122	47	1.801	
-	35.1	130	52	1.753	Contents of ash pit thrown on grate.
-	36.6	136	42	1.680	
-	36.6	138	10	0.826	
-	35.0	142	— 9	-	Dampers of the flue and small furnace closed; valves double weighted.
-	36.0	168	—33	-	Water 0.1 inch below normal level, as at commencement of charging with coal; experiment terminated.
-	37.0	110	—32	-	Water in boiler requires no adjustment.

RESIDUA.

	Pounds.
Clinker	6.75
Ashes	28.50
Ashes behind bridge	1.00
	36.25
Deduct wood ashes	0.608
Total waste from coal	35.642
Coke	9.50
Soot	1.00

TABLE C.—DEDUCTIONS FROM

Experiments on Cambria

	Nature of the data furnished by the respective tables.	1st Trial. (*Tab. XCVI.*)	2d Trial. (*Tab. XCVII.*)
		April 20.	*April* 24.
1	Total duration of the experiment, in hours	23.50	24.5
2	Duration of steady action, in hours	7.25	3.833
3	Area of grate, in square feet	16.25	14.89
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.66	19.85
6	Number of charges of coal supplied to grate	10.0	8.0
7	Total weight of coal supplied to grate, in pounds	1081.75	836.0
8	Pounds of coal actually consumed	1060.0	826 0
9	Pounds of coal withdrawn and separated after trial	21.75	10.0
10	Mean weight, in pounds, of 1 cubic foot of coal	54.0875	52.25
11	Pounds of coal supplied per hour, during steady action	103.27	131.81
12	Pounds of coal per square foot of grate surface, per hour	6.355	8.852
13	Total waste, ashes and clinker, from 100 pounds of coal	9.921	9.489
14	Pounds of clinker alone, from 100 pounds of coal	4.6594	3.3152
15	Ratio of clinker to the total waste, per cent.	46.962	35.094
16	Total pounds of water supplied to the boiler	8390.0	7225.0
17	Mean temperature of water, in degrees Fahrenheit	53°.5	65°.4
18	Pounds of water supplied at end of experiment, to restore level	791.0	1132.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	115.0	156.0
20	Pounds of water evaporated per hour, during steady action	744.82	1048 78
21	Cubic feet of water per hour, during steady action	11.917	16.77
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.973	2.778
23	Pounds of water per sq. ft., by a mean of several observations	2.127	2.709
24	Water evaporated by 1 of coal, from initial temp., (a) final result	7.806	8.558
25	Water evaporated by 1 of coal, from initial temp., (b) during steady action	7.212	9.919
26	Pounds of fuel evaporating 1 cubic foot of water	8.0067	7.303
27	Mean temperature of air entering below ash pit, during steady pressure	58°.19	71°.55
28	Mean temp. of wet bulb thermometer, during steady pressure	–	–
29	Mean temperature of air, on arriving at the grate	288°.625	270°.0
30	Mean temperature of gases, when arriving at the chimney	297°.875	260°.89
31	Mean temperature of steam in the boiler	229°.69	228°.66
32	Mean temperature of attached thermometer	56°.0	69°.0
33	Mean height of barometer, in inches	30.17	29.825
34	Mean number of volumes of air in manometer	8.6394	8.8255
35	Mean height of mercury in manometer	0.195	0.176
36	Mean height of water in syphon draught gauge, in inches	0.2325	0.208
37	Mean temperature of dew point, by calculation	–	–
38	Mean gain of temperature by the air, before reaching grate	230°.435	198°.45
39	Mean difference between steam and escaping gases	68°.185	32°.23
40	Water to 1 of coal, corrected for temperature of water in cistern	7.806	8.528
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.0072	9.7428
42	Pounds of water, from 212°, to 1 cubic foot of coal	487.17	509.06
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	9.9992	10 7642
44	Mean pressure, in atmospheres, above a vacuum	1.4415	1.428
45	Mean pressure, in pounds per square inch, above atmosphere	6.5198	6 3207
46	Condition of the air plates at the furnace bridge	Removed.	Open, (7 rows.)
47	Inches opening of damper, (U. upper)	U. 8	U. 12

TABLES XCVI, XCVII, XCVIII, XCIX.

county (Pennsylvania) coal.

3d Trial. (*Tab. XCVIII.*)	4th Trial. (*Tab. XCIX.*)	Averages.	Remarks.
April 25.	*November* 15.		
22.0	9.30		
11.0833	2.75		
14.89	14 07		
377.5	377.5		
19.85	18.75		
12.0	3.33		
1289.25	340.75		
1271.25	331.25		
18.0	9.5		
53.718	50.75	52.7014	
87.361	79.27	100 428	
5.867	5.634	6.677	
8.84	10.76	9.7525	
3.9324	1.9985	3.4764	
43.867	18.574	36.124	
10480.0	2574.0		
69°.7	44°.0		
1607 0	0.0	-	The fourth experiment having been terminated on the same day on which it was commenced, and the water level in the boiler finally adjusted, no water was added after the temperature had fallen below its usual height; and, consequently, no deduction for temperature of water to restore level is required.
218.0	0.0		
669.295	654.5	779.349	
10.708	10.47	12.466	
1.991	1.734	2.110	
1.971	1.739		
8.072	7.77	8.0515	
7.661	8 257	8.262	
7.7428	8.0438	7.7741	
70°.83	52°.67		
-	46°.0		
346°.50	174°.0	269°.781	
272°.21	255°.5	271°.619	
229°.31	232°.16		
70°.0	49°.96		
29.8975	30.268		
8.8306	5.069		
0.1756	0.551		
0.1985	0.3233	0.2406	The height of the chimney having been increased from 41 to 63 feet, previous to the 4th trial, will account for the greater draught, as indicated by the syphon, in that, than in the three preceding trials.
-	35°.13		
275°.67	221°.83	206°.471	
42°.9	23°.34	41°.664	
8.0606	7.77	8.0411	
9.1742	9.0374	9.2404	
492.82	458.65	486.925	
10.0639	10.127	10.2386	
1.4285	1.4074	1.4263	
6.3278	6.017	6.2963	
Open, (7 rows.)	Closed.		
U. 12	U. 8		

TABLE CI.—*Synoptical view of the character, composition, and efficiency, of free-burning bituminous coals.*

Designation of coals.	Density.						Composition, in 100 parts.						
	Specific gravity.	Pounds per cubic foot, calculated from specific gravity.	Number of experiments, to determine actual weight.	Weight, in pounds per cubic foot, by experiment.	Ratio of actual to calculated weight.	Cubic feet of space required to stow one ton.	Moisture, determined by steam-drying apparatus.	Volatile matter, other than moisture.	Sulphur.	Fixed carbon.	Coke.	Earthy matter.	Ratio of fixed to volatile combustible matter.
Cumberland (Maryland) coals.													
New York and Maryland Mining Co.	1.431	89.435	20	53.700	0.6004	41.713	1.785	12.309	-	73.503	85.906	12.408	5.971
Neff's - - - -	1.337	83.280	40	54.287	0.6519	41.262	2.455	12.675	-	74.527	84.870	10.843	5.880
Easby's "Coal-in-Store" - -	1.307	81.685	11	53.466	0.6545	41.896	0.669	14.984	-	76.264	84.347	8.083	5.089
Atkinson & Templeman's - -	1.313	82.090	22	52.920	0.6446	42.328	0.446	15.632	-	76.688	84.022	7.334	4.937
Easby & Smith's - -	1.332	83.260	44	51.162	0.6144	43.783	0.893	15.522	-	74.289	83.585	9.296	4.786
"Cumberland," (navy yard) -	1.414	88.395	8	53.289	0.6028	42.035	3.125	14.168	0.714	68.438	85.829	14.983	5.000
Pennsylvania (bituminous) coals.													
Dauphin and Susquehanna -	1.443	90.190	26	50.538	0.5603	44.323	0.446	13.547	0.269	74.244	85.738	11.494	5.374
Blossburg - - - -	1.324	82.730	41	53.049	0.6412	42.221	1.339	13.927	0.853	73.108	83.881	10.773	4.946
Lycoming creek - - -	1.388	86.740	29	55.379	0.6384	40.449	0.670	13.807	0.030	71.532	85.493	13.961	5.181
Quin's run - - - -	1.331	83.220	19	50.335	0.6048	44.502	0.836	17.868	0.102	72.787	81.193	8.406	4.046
Karthaus - - -	1.284	80.220	35	52.543	0.6549	42.634	1.282	17.948	1.580	73.770	80.770	7.000	4.110
Cambria county - -	1.407	87.940	33	52.463	0.6079	41.898	2.455	19.019	1.500	69.373	78.526	9.153	3.656

SYNOPTICAL TABLE CI—Continued.

SYNOPTICAL TABLE CI—Continued.

Designation of coals.	Evaporation. Steam, in pounds, corrected for temperature of water in cistern, to: One of fuel, from initial temperature.	One of fuel, from 212°.	One cubic foot of fuel, from 212°.	One of combustible matter, from 212°.	Effect of open air plate: (+ *gain*, — *loss*.) On economy of fuel, per cent.	On rapidity of evaporation, per cent.	Residue from furnace: Total of clinker and ashes, from 100 of fuel.	Clinker alone, from 100 of fuel.	Ratio of clinker to total waste.	Pounds of unburnt coke, after each trial.	Lead reduced from litharge: By one of fuel.	By one of combustible matter.
Cumberland (Maryland) coals.												
New York and Maryland Mining Co.	8.649	9.777	524.85	11.208	— 1.946	— 4.656	12.708	5.426	0.4345	10.125	24.775	30.331
Neff's - - -	8.195	9.442	512.68	10.604	— 5.506	+ 6.916	10.956	4.526	0.4128	6.155	26.457	30.717
Easby's "Coal in-Store" - -	8.880	10.018	535.64	10.935	-	-	8.385	1.326	0.1581	18.250	30.155	32.695
Atkinson & Templeman's - -	9.475	10.699	566.25	11.624	+ 4.198	— 4.465	7.962	2.125	0.2682	5.125	28.490	30.060
Easby & Smith's - - -	8.692	9.965	511.10	11.634	+ 2.538	+ 1.984	9.686	3.045	0.3138	5.350	30.010	33.010
"Cumberland," (navy yard) -	-	-	-	-	-	-	14.526	2.288	0.1575	13.500	24.447	27.979
Pennsylvania (bituminous) coals.												
Dauphin and Susquehanna - -	8.307	9.343	472.85	11.171	+ 5.096	— 8.257	16.368	3.502	0.2160	23.670	25.325	31.183
Blossburg - - - -	8.640	9.724	515.89	10.956	+ 2.578	+ 18.552	11.204	3.396	0.3956	13.750	30.785	32.542
Lycoming creek - - -	7.922	8.911	493.28	10.724	+ 0.457	+ 7.559	16.920	3.262	0.1957	46.250	29.832	32.891
Quin's run - - - -	9.080	10.272	516.98	11.275	+ 1.922	+ 2.189	8.937	1.312	0.1480	14.750	28.554	30.902
Karthaus - - - -	7.925	9.091	477.42	9.887	+ 9.456	+ 7.022	7.894	3.659	0.5038	8.578	31.328	33.309
Cambria county - - -	8.041	9.240	486.92	10.238	+ 8.487	-	9.752	3.476	0.3612	14.810	28.127	31.464

Remarks on the preceding synoptical table.

In reference to density, the above table proves that the mean weight per cubic foot of the six samples from Maryland is 53.137, and that of the six from Pennsylvania 52.551 pounds; or the average of the whole is 52.844. This is 0.506 pound less than the average weight of eight samples of anthracite, as seen above, at page 181. The space for the stowage of one ton is 42.4 cubic feet.

The average evaporation of water per cubic foot of coal from 212°, by eleven samples of the free-burning bituminous class, is 510.35 pounds; while the average for eight samples of anthracite, as seen in page 180, is 509.93. In regard, therefore, to this property, the two classes may be considered, to all intents and purposes, identical.

The average number of cubic feet of water supplied to the boiler per hour, while testing the free-burning coals, is shown in the last column but one, on page 305, to have been 13.726; while from the corresponding column of page 179, it will be seen that the average for eight samples of anthracite was 12.003 cubic feet, showing a difference in favor of the free-burning class of 1.723 ÷ 12.003 = 14.35 per cent. When compared, however, with the two samples of *artificial coke*, as given with the anthracites, at the page last cited, and of which the mean evaporation was 15.708 cubic feet per hour, even the free-burning *coals* are seen to be inferior to the *cokes*. Thus 15.708—13.726 = 1.982 cubic feet, which is 14.44 per cent. of the rate of evaporation by the coals. This circumstance justifies the use of coke in locomotive boilers, in preference to any other fuel, where the price does not interfere to prevent it.

The superior rapidity of action by coke is explicable from the known fact of its porous texture, and the ready admission of air to a vast extent of surface for combustion, resembling, in this respect, the cells in the lungs of animals, which are so admirably fitted to expose large surfaces for the rapid absorption of oxygen in the analogous process of respiration. Coals which contain considerable quantities of vaporizable incombustible matter, such as water and salts of ammonia, or earthy and other carbonates decomposible by heat, are constantly generating, while in combustion, substances which not only, when in contact with the fuel, interfere with rapid combustion, but in the flues occupy the space which would otherwise be left for the true products of combustion to escape with more ease and rapidity.

Having exhibited, in respect to the anthracites, the steam-generating and the lead-reducing power of the unit of combustible matter of each sample in parallel columns, I may here arrange the free-burning coals in reference to the same sets of results. They stand as follows:

	Coals.	Steam to 1 of combustible.	Lead reduced to 1 of combustible.
1	Atkinson & Templeman's	11.624	30.060
2	Quin's run	11.275	30.902
3	New York and Maryland Mining Company	11.208	30.831
4	Dauphin and Susquehanna	11.171	31.183
5	Easby & Smith's	11.034	33.010
6	Blossburg	10.956	32.542
7	Easby's "Coal-in-Store"	10.935	32.695
8	Lycoming creek	10.724	32.891
9	Neff's	10.604	30.717
10	Cambria county	10.238	31.464
11	Karthaus	9.887	33.309
	Mean	10.877	31.736
	Mean for the anthracites (page 181)	10.537	32.517

In examining the right-hand column, or *reductive powers*, of the above table, we perceive that the numbers do not conform, or even approach, to the order of those expressing the *evaporative powers*, but rather tend to the reverse order; and this is true whether we compare the free-burning coals among themselves or their whole class with that of the anthracites.

In confirmation of the general fact that anthracites exhibit a higher reductive power than any of the bituminous class, I may cite the experiments of M. Baudin,* who found the mean reductive power of the combustible matter of the anthracites of Charbonnier, (Brassac,) Messeix, (Haute Dordogne,) and Chambled, (Commentry,) to be 33.52, which is between the results that I obtained for the Lackawanna and Peach Mountain anthracites; and for three different free-burning bituminous coals, (those of Lacombelle, Deux Chaises, and Les Barthes,) varying in volatile matter from 17.7 to 20.2 per cent., he obtained a mean reductive power of 31.393.

* Annales des Mines, tom. 1, 4me serie, 1842, pp. 87, 90, 92, 94.

CLASS III

—

BITUMINOUS CAKING COALS FROM THE EASTERN COAL FIELD OF VIRGINIA, IN THE NEIGHBORHOOD OF RICHMOND.

—

SAMPLES.

No. 1. Barr's Deep Run.
2. Crouch & Snead's.
3. Midlothian 900 feet shaft, (average.)
4. Creek Company's.
5. Clover Hill.
6. Chesterfield Mining Company's.
7. Midlothian *average.*
8. Tippecanoe.
9. Midlothian "new shaft."
10. Midlothian *screened.*
11. Midlothian, (navy yard, Washington.)

General characters.

The range of specific gravities in this class is nearly the same as in that of the free-burning coals; but the *average* is rather less. The average weight per cubic foot is also less by about 3.5 pounds. These coals burn with a long flame and much smoke—giving an intumescent, coherent coke, preserving nothing of the original form of the coal.

No. 1.

ious coal from Deep Run mines, in the neighborhood of Richmond, Virginia, sent for trial by John Barr, Esq.

mpanying this sample was the following letter from the proprietor:

"RICHMOND, *October* 10, 1843.

AR SIR: Having been informed, through J. R. Anderson, Esq., that d only a small portion of the sample of coal sent by me to the navy ome time ago, I now beg leave to hand you annexed bill of lading ir hogsheads of Deep Run coal, shipped per the schooner Wm. H. n, on which I have paid the freight.

ou will confer a favor by testing its qualities; and I should be glad if ould inform me of the result at your convenience.

"Respectfully, your obedient servant,

"JOHN BARR,
"per J. J. VAUGHAN.

rofessor JOHNSON,
"*Navy Yard, Washington.*"

sides the four hogsheads of the coal mentioned above, a single hogs-, left from a sample previously received at the yard, was included in the sample tried for evaporative power, and its effect is given in the table of the fifth trial.

The exterior characters of the Deep Run coal are a jet-black color and shining surface, particularly in the main partings. The distinctness of these, and their nearness to each other, give the coal the appearance of being foliated.

In this, as in several of the bituminous coals of Pennsylvania, the main partings are at an angle of 85° with the surfaces of deposition. The facility with which the coal separates at the main partings, causes it to fall mostly into small pieces; and this circumstance gives the average weight per cubic foot probably somewhat higher than it would have been had the whole been in the state of lumps. The cross partings give rather irregular surfaces; but there is a general tendency to form rhombic prisms.

The specific gravity of two specimens, *a* and *b*, was 1.4023 and 1.3623; from the mean of which, the weight of a cubic foot of solid coal is 86.41 pounds.

During the experiments on evaporation, 48 charges, of 2 cubic feet each, gave, as the mean weight per cubic foot, 53.174 pounds. Hence the *actual* weight, in the condition in which the coal was received, is 0.6153 of the calculated weight from specific gravity. The space required for 1 ton is 42.126 cubic feet.

The moisture expelled in drying portions of the two specimens was, for *a* 0.75, and for *b* 0.5. In the steaming apparatus at the navy yard, 28 pounds lost in four days 8 ounces, or 1.785 per cent.

The volatile matter, other than moisture, from specimen *a* was 19.2, and from *b* 19.2. The earthy matter in *a* was 14.919, and that in *b* only 5.086. Hence the fixed carbon in *a* is 65.131, and in *b* 75.214. Volatile to fixed combustible 1 : 3.392, and 1 : 3.917.

Besides the preceding analyses, an experiment was made on about forty

fragments from as many different specimens of the coal, (some from each cask,) which gave the following result:

Moisture - - - - - - -	0.628
Other volatile matter - - - - - -	19.782
Earthy matter - - - - - - -	11.468
Fixed carbon - - - - - - -	68.122
	100.

Hence it appears that the fixed is to the volatile combustible as 68.122 : 19.782=3.443 : 1.

The coke of this coal, when produced rapidly, is intumescent; and the vessel in which the coking process is performed is represented by a cast which fills the interior; and the mass, on being cut through, exhibits distinct concentric layers, indicating a succession of stages in the process of coking. The vacant spaces between the concentric shells are less in amount than the solid parts of the mass.

The ashes, from analysis, vary in color from yellowish white to nearly flesh-red; those from the mixture of forty fragments are of a very light fawn color.

During the five trials on evaporation, there were burned 5,072.75 pounds of this coal; and the total waste from the furnace in the state of *ashes* was 319.39, and in clinker 244 pounds. From the flues were obtained 21.5 pounds of soot.

The ashes gave by reincineration 12.1 per cent. of combustible matter, the clinker 0.873, and the soot 54.71 per cent. This reduces the total incombustible residuum from all these sources to 531.35 pounds, or 10.475 per cent of the coal burned.

The following may, therefore, represent the proximate constituents of this sample by the large analysis actually carried on, in part, in the furnace, viz:

Moisture, by drying 28 pounds - - -	1.785	per cent.
Other volatile matter, from 40 specimens - -	19.782	"
Earthy matter, from 5,072.75 pounds - -	10.475	"
Fixed carbon, by difference - - -	67.958	"
	100.	

Which gives the volatile to the fixed combustible 1 : 3.4354.

The ashes weigh 44.86, the clinker 33.5, and the soot 12.23 pounds per cubic foot. The clinker is in large black porous masses, evincing much fusibility, glazing and incrusting the shaly and other foreign matter mixed with it. It manifests some tendency to spread out into sheets, but does not attach itself with any considerable force to the grate bars. When pulverized and completely calcined, its color becomes a dark brown, while the residuum from the ashes is of a red gray, and that from the soot a lighter red, nearly approaching to fawn-colored.

A trial of specimen *b* with oxide of lead resulted in reducing 24.94 times its weight of metallic lead. This, after deducting earthy matter and moisture, shows the combustible ingredients to possess a reducing power of 26.416. Quantity of coal essayed, 20 grains.

Fearing there might be some source of error in the preceding trial, I took a portion of the mixture of 40 specimens, performed the experiment with caution, and obtained 24.62 times its weight of lead. Coal used, 10 grains; lead to 1 of combustible, 28.007.

In the chain shop, this coal burned with a long flame, with no extraordinary amount of smoke, gave a lively heat, and was pretty well adapted to making chain. Sixty pounds of it put in eight links of $1\frac{1}{8}$-inch chain. The coke is light, and rather difficult to be kept in place before a strong blast.

In the ordinary smith work, to which it was applied in the anchor shop, it was found "a strong coal," making a hollow fire, which stood a long time.

The amount of volatile matter is insufficient to render this a suitable coal for gas-making purposes. For domestic applications it possesses the quality of giving a lively fire, with much less smoke than most other samples from the Virginia coal field to which it belongs.

The accendibility of the coal is indicated by the lengths of time taken to bring the boiler to steady action, which, in the several trials, were as follows:

First trial	1.416 hour.
Second trial	1.700 "
Third trial	1.400 "
Fourth trial	1.583 "
Fifth trial	1.500 "
Mean	1.520 "

or 1 hour and 31 minutes.

The mean weight of coke left after each trial, besides what passed the sieve and was weighed with the ashes, was only 6.4 pounds.

First trial—upper damper 8 inches open; air plates closed;

				TEMPERATURES OF THE										
		...er.		Air entering back of grate.			Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volume of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
Oc...				131			165	47	30.05	0.371	[illegible]	0.12	–	–
				122	240	62	215	51	30.05	0.474	5.81	0.30	–	–
				126	238	62	230	52	[illegible]	0.582	4.76	0.29	–	109.00
				136	223	62	230	52	30.06	0.536	5.20	0.31	108	104.00
				141	233	62	229	53	30 06	0.558	5.00	0.37	278	–
				146	270	62	230	53	30.05	0.564	4.94	[illegible]	[illegible]	–
				156	279	62	230	53	30.05	0 566	4.90	0.40	1018	–
				172	286	63	230	[illegible]	30.05	0.558	5.00	0.40	1313	106 00
				187	285	63	230	54	30.04	0.557	5.01	0.28	[illegible]	–
				198	294	63	230	55	30.05	0.566	4.92	0.49	2346	104.50
	2.30	62	54.5	206	306	63	232	56	30 05	0.563	4.94	0.38	2668	101.75
	3.00	63	55	213	288	–	233	56	30.05	0.554	5.03	0.33	2668	–
	3.30	63	55	224	288	–	232	57	30.05	0 564	4.94	0 34	2668	–
	4.05	64	56	240	280	60	232	58	30.07	0.540	5.16	0.32	2668	103.00
	4.30	63	55	244	280	60	232	58	30.07	0.563	4.95	0.35	3857	100.25
	5.20	60	52	248	296	59	231	58	30.08	0 560	4.98	0.32	5285	93.00
	6 00	60	52	252	310	59	232	57	30 09	0.568	4.90	0.35	5641	–
	6.15	59	51	258	303	60	231	58	30.11	0.564	4.94	0.33	6451	–
	11.00	52	45	224	199	58	226	50	30.13	0.505	5.52	0.23	6671	–
	A. M.													
Oct. 24	6.20	41	40	189	180	56	211	45	30.17	0.375	6.80	0.20	6672	–
	6.40	40	39	174	179	56	210	45	30.17	0.374	6.81	0.20	6735	–

Period of steady action, from 0*h*. 50*m*. to 5*h*. 46*m*. p. m.—4*h*. 56*m*.; coal supplied to the grate, 506.3 lbs., water to the boiler, 4,168.4 lbs.; water to 1 of coal for the same period, 8.229. The column of "remarks" will show the cause of suspending the supplying of water for a portion of the time between 2*h*. 30*m*. and 4*h*. 30*m*. p. m; the evaporation, however, still proceeded at about the average rate.

(DEEP RUN) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.	–				Morning clear; wind NW., brisk; the grate, ash pit, and flues, cleaned out this morning.
–	35.1	82	—31	–	Water 0.82 inch below normal level; commenced firing on grate and in small furnace.
–	33.3	72	+25	–	Water in boiler 0.28 inch below normal level, to raise it to which, 56 lbs. were added.
10.35	33.1	78	8	–	Wood consumed, 267.75 lbs.; commenced charging with coal; steam blows off.
10.58	36.6	82	— 17	0.687	
–	38.2	86	+ 4	0.901	
–	36.8	90	40	2.172	
–	36.8	102	49	1.748	Placed 28 lbs. of this coal in drying apparatus.
0.50	37.2	114	58	2.622	
–	40.1	129	55	2.341	
1.55	40.6	138	64	2.071	Second weight taken from back valve at 2h. 8m. p. m., to avoid discharge of spray by front valve.
2.27	47.8	144	74	1.706	
–	47.6	150	55	–	Water in boiler 1.3 inch below normal level; water in the river too low to fill tank.
–	47.6	161	56	–	Water in boiler 2 inches below normal level.
3.52	49.0	176	48	–	Tank partly filled: water 3.3 inches below normal level.
4.28	47.6	181	48	–	Water brought to within 2 inches of normal level.
5.46	43.8	188	65	2.447	
–	43.2	192	78	1.414	
–	41.7	199	72	–	Contents of ash pit on grate at 6h. 10m.; water in boiler 1 inch above normal level; damper 4 inches.
–	33.2	172	+27	–	Water in boiler found 0.65 inch below, raised to 0.2 inch below normal level; damper closed.
–	37.8	148	—31		
–	36.7	134	—31	–	Water in boiler adjusted for temperature.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	33.50
Ashes - - - - - - - - - - -	52.50
Ashes behind bridge - - - - - - - - -	3.28
Total clinker and ashes - - - - - - - -	89.28
Deduct wood ashes - - - - - - - - -	0.822
Total waste from coal - - - - - - - -	88.458
Coke - - - - - - - - - - -	9.00

TABLE CIII.—BARR'S

Second trial—upper damper 8 inches open; air plates open;

Date.	Hour.	TEMPERATURES OF THE ...entering ash pit.	...ib thermometer.	...ing back rate.	...ing chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
					79	56	210	45	30.17	0.374	6.81	0.20	-	-
					90	57	231	45	30.17	0.560	4.76	0.28	-	98.25
					18	57	228	45	30.17	0.537	5.20	0.30	86	-
					39	57	229	47	30.17	0.563	4.94	0.32	162	-
					94	58	231	49	30.17	0.570	4.88	0.38	480	102.25
					08	58	232	53	30.16	0.570	4.88	0.36	940	-
					98	53	231	54	30.16	0.570	4.88	0.38	1353	-
					16	53	232	54	30.16	0.575	4.82	0.39	1580	106.75
					04	54	231	55	30.14	0.553	5.04	0.34	1995	-
					00	54	231	56	30.14	0.572	4.86	0.39	[illegible]	106.00
					92	53	231	57	30.14	0.557	5.01	0.36	2575	-
					95	54	230	57	30.13	0.550	5.07	0.33	2910	103.25
					19	54	232	58	30.13	0.576	4.81	0.42	3170	-
					25	54	230	59	30.13	0.562	4.96	0.36	3562	105.50
					42	54	232	60	30.13	0.583	4.75	0.42	4060	-
					46	54	232	60	30.11	0.580	4.78	0.43	4614	105.00
					36	57	231	60	30.11	0.565	4.92	0.39	5086	-
					26	57	231	60	30.10	0.578	4.84	0.39	5557	108.25
					13	57	231	59	30.11	0.578	4.84	0.39	6029	100.00
					48	57	232	59	30.11	0.580	4.78	0.43	6527	-
					38	57	231	59	30.11	0.580	4.78	0.41	7016	107.00
					33	57	228	59	30.11	0.553	5.04	0.36	7956	-
					39	57	226	57	30.10	0.536	5.41	0.25	7996	-
					93	58	220	55	29.98	0.486	5.69	0.20	7996	-
					94	57	219	56	29.98	0.471	5.84	0.21	8117	-

Period of steady action, from 11*h*. 47*m*. a. m. to 5*h*. 28*m* p. m.=5*h*. 41*m*.; coal supplied to grate, 699 pounds; water to boiler, 4,677.48 pounds, water to one of coal, 7.436. In filling the tank, care was generally taken to anticipate the period when the supply would be suspended, by raising the level in the boiler as much above the normal line as would leave it at that line when the tank was filled.

(DEEP RUN) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	36.7	134	—31	-	Morning clear; heavy frost; commenced firing; lower damper opened.
7.48	31.6	104	—41	-	Wood consumed, 120.5 lbs.; commenced charging with coal;
-	37.0	116	—15	0.322	lower damper closed, and upper opened; steam escapes at 8*h.* 1*m.*
-	36.6	114	+ 9	0.408	Air plates opened, as usual, only when the fire has got into good activity.
9.30	36.6	108	53	1.738	
-	41.1	121	76	1.589	Wind W., light; filled tank at 10*h.* 18*m.*
-	42.6	126	67	2.188	
10.52	39.8	129	84	0.885	
-	40.1	134	73	2 517	
11.47	39.0	137	69	1.764	Commenced drawing gases at meridian; drew in 33 minutes 100 cubic inches, which gave water 0.85 grain, carbonic
-	40.6	137	61	1.203	acid 2.71 grains, oxygen 17.258 cubic inches; fire dull;
1.06	42.2	143	65	1.775	temperature of bath, 57°.5.
-	43.7	144	87	1.377	Fire now very brisk.
1.57	44.3	143	95	2.077	Grate bars heated to a cherry redness during the day; in part
-	45.8	149	110	2.638	caused by the constant fire in the ash pit, from the fine coal
2.51	45.8	167	114	2.515	falling through the grate.
-	49.5	175	105	3.064	Filled tank at 3*h.* 33*m.* p. m.
3.48	46.7	192	95	2.442	
4.32	47.6	195	82	2.554	Filled tank again at 4*h.* 57*m.* p. m.
-	46.7	197	116	2 216	
5.28	48.5	191	107	3.109	Wind SE.; second weight removed from the back valve.
-	43.7	210	105	-	Air plates closed, and contents of ash pit put on grate at 6*h.* p. m.
-	44.3	213	13	-	Damper reduced to four inches; at 7*h.* 45*m.* p. m. double weighted both valves; closed damper and air port.
-	52.0	164	—27	-	Water in boiler 0.45 inch below normal level; raining.
-	51.0	149	—25	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	51.00
Ashes	51.25
Ashes behind bridge	4.13
Total clinker and ashes	106.38
Deduct wood ashes	0.37
Total waste from coal	106.01
Coke	5.00

TABLE CIV.—BARR'S

Third trial—upper damper 8 inches open; air plates closed;

ption.	Weight of water supplied to boiler.	Weight of charges of coal.
11	-	-
16	-	107.25
12	85	-
0	512	103.75
2	849	-
10	1259	107 50
10	1756	-
11	2179	107.75
10	2435	-
18	2774	103.50
12	3183	-
13	3525	105.25
10	4169	-
12	4571	106.25
4	4981	-
19	5421	105.50
18	6061	-
36	6729	108.00
15	7143	-
35	7570	108 75
30	8251	-
30	8391	-
26	8411	-
19	8452	-

Period of steady action, from 10*h.* a. m. to 5*h.* 7*m.* p. m.—7*h.* 7*m.*; coal supplied to the grate, 745 lbs.; water to the boiler, 6,197.13 lbs.; water to 1 of coal, 8.305.

N. B. After this trial, it was found that one row of holes in the air plates had been burned out, reducing them to 13×34=442 holes, ½ inch in diameter.

(DEEP RUN) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
–	51.0	149	–25	–	Morning cloudy, with rain; wind SE., fresh; commenced firing.
7.36	53.2	131	+10	–	Wood consumed, 55 lbs.; commenced charging with coal.
–	51.2	123	12	0.250	Damper set 8 inches.
9.00	52.4	122	68	2.236	
–	51.2	129	95	1.785	
10.00	51.2	129	116	2.172	Filled tank at 10*h.* 6*m.* a. m.
–	52.8	151	103	2.628	Coke and coal pass in considerable quantities through the grate.
10.46	52.4	165	98	2.246	
–	52.8	186	88	1.356	A slight irregularity of action occurred at 11*h.* 15*m.* by the falling of some of the grate bars, which had become warped and deranged by being over-heated.
11.58	49.8	179	85	1.796	
–	54.8	183	103	2.167	
1.12	54.0	183	103	1.812	
–	55.3	183.5	112	3.412	
2.10	55.7	184	127	2.130	
–	55.7	185	126	2.172	
3.00	56.9	191	124	2.231	Filled tank at 3*h.* 18*m.* p. m.
–	56.9	191	115	3.391	Little smoke from chimney to-day, except when stoking or charging.
4.14	55.7	196	107	2.359	Wind NW., very light; sun shining; commenced drawing gases at 4*h.* 46*m.*; drew in 30 minutes 5 seconds 100 cubic inches, which gave water 1.36 grain, carbonic acid 4.98 grains, oxygen 11.875 cubic inches; temperature at mercurial bath, 59°; contents of ash pit thrown on grate at 5*h.* 30*m.* p. m.
–	55.7	199	116	2.198	
5.07	57.1	204	107	2.262	
–	57.1	210	106	–	Water in boiler left 1.1 inch above normal level; damper reduced to 4 inches.
–	54.8	212.5	40	–	Water left at 0.3 inch below normal level; damper and air plate closed.
–	51.4	238	–40	–	Water left at 0.02 inch below normal level.
–	42.9	124	–32	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	43.75
Ashes - - - - - - - - - - -	70.50
Ashes behind bridge - - - - - - - -	4.23
	118.48
Deduct wood ashes - - - - - - - -	0.169
Total waste of coal - - - - - - - -	118.311
Coke - - - - - - - - - - -	5.75

TABLE CV.—BARR'S

Fourth trial—upper damper 8 inches open; air plates half

	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
59	0.362	6.97	0.16	–	–
31	0 470	5.85	0.33	–	–
31	0.550	5.07	0.31	–	106.00
32	0.540	5.17	0 33	159	107.75
31	0.543	5.14	0.36	477	–
31	0.554	5.03	0.40	807	–
32	0 549	5 08	0.38	1143	–
32	0 548	5.10	0.36	1535	103.50
32	0.535	5.22	0.35	1785	–
32	0 543	5 14	0.35	2147	103.75
33	0 550	5.07	0.39	2302	–
31	0.548	5.10	0.39	2695	113.50
30	0.550	5.07	0.38	3037	–
32	0.550	5.07	0.39	3449	109.00
32	0 550	5.07	0.40	3947	–
32	0 560	5.07	0.37	4369	103.00
33	0.546	5.10	0.36	4807	–
33	0.557	5.01	0.37	5179	104.50
33	0.549	5.08	0.37	5507	–
34	0.540	5.17	0.35	5687	109.50
34	0.560	4	0	[illegible]	–
35	0.552	5	9	6722	–
59	0.558	5	[illegible]	7227	107.25
59	0.540	5	4	7723	–
76	0.514	5	9	7900	–
46	0.495	5	1	7904	–
09	0.465	5	1	7942	–
09	0.463	6.12	0.30	7966	–

Period of steady action, from 10*h*. 26*m*. a. m. to 5*h*. 42*m*. p. m. = 7*h*. 16*m*.; coal supplied to grate in that time, 749.5 lbs.; water to boiler, 5,639.27 lbs.; water to 1 of coal, 7.523.

(DEEP RUN) COAL.

open; steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
					Wind NW., fresh; raining; water in boiler 0.73 inch below normal level; fire in small furnace.
h. m.					
-	38.2	70	—18	-	Commenced firing at 5h. 30m. a. m.
-	40.2	77	+61		
7.40	42.9	80	41	-	Wood consumed, 235.25 lbs.; commenced charging with coal; steam blows off at 7h. 47m.
8.26	40.0	88	39	0.476	
-	42.9	90	64	1.444	Nearly a charge of fine coal in the ash pit passed through grate.
-	42.6	95	97	1.748	Air plates half opened; coal from ash pit returned to fire.
-	43.8	115	81	1.780	Wind NW., brisk; clearing off; steam allowed to escape from back valve at 10h. 30m.
10.26	45.1	121	88	2.077	Commenced drawing gases at 10h. 32m. a. m.; drew in 60 minutes (at various intervals, until 1h. 29m. p. m.) 100 cubic inches; which gave water 0.80 grain, carbonic acid 4.53 grains, oxygen 13.75 cubic inches; temperature of bath, 54°. Filled tank at 11h. 34m.
-	46.3	137	91	1.324	
11.43	45.2	151	80	1.759	
-	45.2	156	96	1.297	Coal continues to pass in large quantities through grate; returned to fire.
0.40	46.5	167	100	1.764	
-	46.8	171	108	1.812	
1.55	50.7	179	110	2.182	
-	48.1	186	128	2.108	
2.45	48.5	185	126	2.713	
-	49.4	191	122	2.691	
3.45	48.2	191	113	1.653	
-	48.5	191	125	2.607	Filled tank at 4h. 28m. p. m.
4.17	46.8	194	103	2.013	
-	48.1	200	118	1.570	
[illegible]	49.4	203	130	3.110	Coal burned to-day all fine.
5.42	49.1	209	128	2.675	Air plates closed; cloudy since sunset.
-	45.4	212	97	-	Contents of ash pit on grate; water 1.1 inch above normal level.
-	41.1	210	20	-	Water at 0; both valves double weighted; pressure rises.
-	35.1	167	—34	-	Water 0.28 inch below normal level.
-	35.1	165	—33	-	Water 0.2 inch below normal level.
-	41.1	148	—36.5	-	Water adjusted in boiler.

RESIDUA.

	Pounds.
Clinker	49.00
Ashes	53.50
Ashes behind bridge	4.35
Total clinker and ashes	106.85
Deduct wood ashes	0.722
Total waste from coal	106.128
Coke	5.50

TABLE CVI.—BARR'S

Fifth trial—upper damper 8 inches open; air plates closed; steam thrown into

Period of steady action, from 8h. 56m. a. m. to 3h. 45m. p. m.=6h. 49m. Coal supplied to grate, 790.5 lbs.; water to boiler, same time, 6,129 lbs., or, to 1 of coal, 7.753.

(DEEP RUN) COAL.

chimney; small furnace in action, and additional weights on safety valves.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	41.1	148	—36.5	-	Morning clear; wind NW., light; commenced firing.
7.03	37.4	135	+63	-	Wood consumed, 81½ lbs.; commenced charging with coal.
8.00	34.3	127.5	66	-	Steam escapes under four weights (about 126 pounds) on each valve; making, with the weight of the valve, 19 pounds per square inch. Damper set 8 inches at 8*h*. 0*m*. a. m.
-	38.2	133	91	1.146	
8.56	38.1	142	116	2.622	
-	38.2	160	117	2.634	
10.03	38.5	165	103	2.288	Filled tank at 10*h*. 0*m*. a. m.
-	36.8	168	115	1 303	
10.57	40.1	174	130	2.638	Wind NE , brisk; clear.
-	37.2	183	128	2.214	
11.40	39.0	186	119	2.872	
-	40.1	192	121	2.903	Occasionally the grate bars become red.
0.50	40.1	202	104	1.865	
-	40.6	205	110	2.787	
1.45	43.7	204	124	1.649	Coal in drying apparatus weighed to-day 27 lbs. 8 oz.
2 34	43.7	211	104	2.792	
-	43.7	212	106	1.749	Filled tank at 3*h* 10*m*.; part of the coal burned to-day is in lumps, causing the fire to burn more vigorously than before; a large amount, notwithstanding, passes through grate; contents of ash pit thrown on grate 4*h*. 15*m*.
-	45.1	211	112	2.198	
3.54	45.1	216	107	3.195	
-	38.5	217	97	-	Extra weights removed at 5*h*. 0*m*.; water in b 0.2 inch above normal level.
-	39.6	218	— 1	-	Water left at 0.3 inch below normal le
-	35 6	162	—30	-	Water 0.43 inch below norma
-	35.6	160	—30	-	Water in boiler adjusted.

RESIDU

Clinker - - - -
Ashes - - - -
Ashes behind bridge - -

Total ashes and clinker -
Deduct wood ashes - -

Total waste from coal - -

Coke - - - - -

Soot - - - - -

TABLE CVII.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (*Table CII.*)	2d Trial. (*Table CIII.*)
		October 23.	*October* 24.
1	Total duration of the experiment, in hours	22.333	24.333
2	Duration of steady action, in hours	4.933	5.083
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	8.0	10.0
7	Total weight of coal supplied to grate, in pounds	825.5	1042.25
8	Pounds of coal actually consumed	816.5	1037.25
9	Pounds of coal withdrawn and separated after trial	9.0	5.0
10	Mean weight, in pounds, of one cubic foot of coal	51.5937	52.1125
11	Pounds of coal supplied per hour, during steady action	102.676	110.681
12	Pounds of coal per square foot of grate surface, per hour	7.297	7.866
13	Total waste, ashes and clinker, from 100 pounds of coal	10.833	10.217
14	Pounds of clinker alone, from 100 pounds of coal	4.0627	4.8977
15	Ratio of clinker to the total waste, per cent.	37.501	47.933
16	Total pounds of water supplied to the boiler	6735.0	8117.0
17	Mean temperature of water, in degrees Fahrenheit	60°.3	55°.6
18	Pounds of water supplied at the end of experiment, to restore level	63.0	123.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	9.0	17.0
20	Pounds of water evaporated per hour, during steady action	845.003	823.065
21	Cubic feet of water per hour, during steady action	13.52	13.169
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.238	2.18
23	Pounds of water per square foot, by a mean of several observations	2.237	2.227
24	Water evaporated by 1 of coal, from intial temp. (a) final result	8.225	7.809
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	8.229	7.436
26	Pounds of fuel evaporating one cubic foot of water	7.5988	8.0036
27	Mean temperature of air entering below ash pit, during steady pressure	59°.43	60°.77
28	Mean temp. of wet bulb thermom., during steady pressure	51°.46	52°.41
29	Mean temperature of air, on arriving at the grate	197°.50	213°,0
30	Mean temperature of gases, when arriving at the chimney	280°.0	317°.06
31	Mean temperature of steam in the boiler	230°.93	231°.2
32	Mean temperature of attached thermometer	55°.29	56°.94
33	Mean height of barometer, in inches	30.051	30.132
34	Mean number of volumes of air in manometer	4.991	4.8706
35	Mean height of mercury in manometer, in atmospheres	0.5584	0.5699
36	Mean height of water in syphon draught gauge, in inches	0.3611	0.3933
37	Mean temperature of dew point, by calculation	42°.31	45°.88
38	Mean gain of temperature by the air, before reaching grate	138°.07	152°.23
39	Mean difference between steam and escaping gases	58°.11	92°.17
40	Water to 1 of coal, corrected for temperature of water in cistern	8.225	7.89
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.4364	8.9947
42	Pounds of water, from 212°, to 1 cubic foot of coal	486.86	468.74
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.5829	10.0183
44	Mean pressure, in atmospheres, above a vacuum	1.4373	1.4733
45	Mean pressure, in pounds per square inch, above atmosphere	6.4577	6.9894
46	Condition of the air plates at the furnace bridge	Closed.	Open
47	Inches opening of damper, (U. upper)	U 8	U. 8

TABLES CII, CIII, CIV, CV, CVI.

Barr's (Deep Run) coal.

3d Trial. (*Table CIV.*)	4th Trial. (*Table CV.*)	5th Trial. (*Table CVI.*)	Averages.	Remarks.
October 25.	*October* 27.	*October* 28.		
24.667	25.167	25.25		
7.116	7.267	6.966		
14.07	14.07	14.07		
377.5	377.5	377.5		
18.75	18.75	18.75		
10.0	10.0	10.0		
1068.5	1065.75	1107.75		
1057.75	1060.25	1101.0		
5.75	5.5	6.75	6.40	
53.175	58.2875	55.3875	53.1112	
101.694	103.137	113.479	106.933	
7.441	7.33	8.065	7.5998	
11.185	10.009	13.124	11.0736	
4.1305	4.598	6.0518	4.7481	
36.928	45.935	46.108	42.881	On the 2d and 5th trials the mean rate of combustion was considerably more rapid than on the other three days; and the proportion of clinker, on those two trials, is even more above that of the other three days than the rate of evaporation; showing the effect of rapid combustion in vitrifying the earthy materials.
8452 0	7966.0	8394.0		
56°.5	52°.4	52°.0		
38.0	66.0	80.0		
5.0	4.0	12.0		
870.874	775.873	879.84	838.931	
13.927	12.414	14 077	13.421	
2.306	2.055	2.313	2.218	
2.299	2.045	2 322		
7.985	7.51	7.613	7.8284	
8.305	7.522	7.753	7.8490	
7.8272	8.3323	8.2096	7.9923	
63°.21	57°.42	58°.44		
58°.06	52°.29	50°.31		
237°.94	222°.26	243°.67	222°.874	
337°.29	337°.75	371°.31	328°.68	A gradual increase of temperature in the escaping gases is visible from the first to the fifth trial.
231°.82	232°.26	258°.375		
59°.06	53°.03	53°.75		
29.949	29.626	30.067		
5.053	5.081	2.867		
0.5519	0.5491	0.7743		
0.3969	0.368	0.3914	0.3821	
54°.14	46°.91	40°.51		
174°.73	164°.84	185°.23	168°.02	
108°.23	109°.2	112°.93	96°.528	In the first experiment, which gave the highest result in evaporative effect, the excess marked in this line is far less than in either of the rest—due, probably, to the clean condition of the flues; and the increase of the excess is attributable to the gradual coating of the same with soot and dust.
7.985	7.51	7.613	7.8446	
9.1906	8.6737	8.7956	9.0182	
488.71	462.2	487.17	478.736	
10.348	9.6384	10.1243	10.1424	The 2d and 4th trials, both with air plate open, give results below the average of the rest.
1.4262	1.4084	2.2977	1.4368	The 5th trial is omitted in this average, and the following, as the experiment, in regard to pressure, was not intended to be comparable with the rest.
-6.295	-6.0822	19.164	6.4436	
Closed.	Half open.	Closed.		
U. 8	U. 8	U. 8		

Remarks on the preceding table of deductions.

The combustion of this coal evidently produced a pretty rapid as well as uniform rate of evaporation; and this circumstance, as well as its composition, entitles it to rank, if not *among* the free-burning class, at least in near proximity to those which have been thus denominated. It belongs to a place intermediate between those which in France are designated as *dry coals with short flame*, and those called *fat coals with short flame.**

The average rate of evaporation per hour, (13.421 cubic feet,) as found in the 21st line of the table, differs from that of the free-burning class by only three-tenths of a cubic foot.

The fifth trial of this coal afforded an opportunity of studying the influence on the economy of fuel of working at an increased pressure, as had been done in the case of the Peach Mountain anthracite. The effect is entirely in accordance with what was given in that case; and the observations on temperature of escaping gases, in the 30th and 39th lines of the table, point significantly to the cause of the inferiority of the result. Not only was the temperature of the escaping gases absolutely higher at the high than at the low pressure experiment, but, relatively to the temperature of steam in the boiler, it gave a greater excess of temperature over the high steam than it had over the low. Thus, on the fifth day's trial, (the 28th of October,) the steam was at a mean temperature, during steady action, of 258°.37, and the escaping gases at 371°.31: difference, 112°.94. At the third trial, (on the 25th of October,) the damper and air plate being in the same condition as on the 28th, the mean temperature of escaping gases was 337°.29, and that of the steam 231°.82; and their difference 105°.47. Now, 112.93—105.47=7°.46=the excess of difference on the day of working high steam above that of using it at the ordinary range adopted for the experiments. This small excess may possibly be assignable to the coating of soot which had accumulated in two days. If, however, the whole of the superior temperature of the gases be due to the higher temperature maintained in the boiler, its effect in diminishing the evaporative effect of the unit weight of fuel can readily be computed from data actually obtained while burning this coal. On the 25th of October, the analysis of gases entering the chimney proved that 19.965 pounds of air passed through the fire while burning a pound of coal; and that the dry gases, from the combustion of a pound of coal, were equivalent, in capacity for heat, to 20.477 pounds of air, or to 5.465 pounds of water. Hence, by heating those gases to 371°.31, instead of 337°.29, or 34° hotter in one case than in another, a *heating power* is expended on the gases, and lost to the boiler, of 5.465× 34=185°.81; and this divided by 1030 gives 0.1804, as the evaporative effect of the temperature imparted to the gases in the one case more than in the other. If the first trial be compared with the fifth, the difference in temperature of escaping gases is 371°.31—280°=91°.31; and this multiplied by 5.465, gives 499 as the excess of *heating power*, or 0.4845 of *evaporative power* expended on the gases in the fifth trial above that in the first.

* "*Houilles sèches à courte flamme,*" and "*houilles grasses à courte flamme.*"—See *Annales des Mines*, tome 1, 4ème série, p. 88.

No. 2.

Bituminous coal from Crouch & Snead's mines, Henrico county, Virginia.

No letter or certificate accompanied this sample of coal. A memorandum on the bill of lading merely signified that it was from the above-named mines, and that their distance from Richmond, by James and Kenawha river canal, is 12 miles.

In exterior appearance, this coal is either columnar or foliated. The alternate plies of bright and dull matter are generally very thin. The main partings are inclined 85° to the surfaces of deposition. The cross partings are not well defined. On the main partings are occasionally seen efflorescences of sulphate of iron; and along the lines are cracks, manifesting the effect of the air, which, in less than eighteen months, has begun to disintegrate the coal by the decomposition of its sulphuret of iron.

The specific gravity of specimen *a* of this coal, which I analyzed, was found to be 1.4513, and that of *b* 1.8347; the latter being of a very *sluty* appearance. This gives the mean weight of one cubic foot of the solid coal 107.69 pounds; but taking *a* alone, it would be but 90.71, which I am inclined to adopt as the weight of the true coal.

The mean result of thirty-six trials in the charge box is 53.593 pounds per cubic foot; the highest number being 56.378, and the lowest 50.5, of which the mean is 53.437. Hence, the calculated is to the merchantable weight as 90.71 : 53.593=1 : 0.5908. The space to receive one gross ton is 41.797 cubic feet.

The proportion of moisture obtained from analysis of specimen *a* was 0.957, and that from *b* was 0.955 per cent. From 28 pounds, exposed for three and a half days in the steaming apparatus, were expelled 8 ounces, or 1.785 per cent. of moisture. Of other volatile ingredients, besides moisture, *a* gave 26.103, and *b* 22.895 per cent.

Dr. King obtained from one specimen 27.25, and from another 21.5 per cent. of volatile matter, including moisture. Hence, deducting for these two the same proportion of moisture as found in the other specimens, we have the *volatile combustible* matter as follows:

	Specimen *a*	26.103
	Specimen *b*	22.895
Dr. King's trials.	Specimen *c*	26.294
	Specimen *d*	20.544
	Mean	23.959

Of sulphur, specimen *b* afforded 0.4271 per cent.

Four incinerations of specimen *a* gave 8.72, and one of *b* 41.56 per cent. of incombustible matter, of a dirty white color, slightly tinged with red. A trial on the purer plies of *b* gave but 6.22 per cent.

During the trials of evaporation, 3,834.75 pounds of coal burned, yielded of ashes 346.406, and of clinker 205.94 pounds. On reincineration, the former lost 7.288 per cent. of their weight, and the latter 0.95 per cent. Of soot and dust, after all the trials, there were obtained 34.75 pounds, of

which 66.49 per cent. was incombustible matter. The three reductions being made, show of incombustible matter—

From the ashes, to be	321.438	pounds.
From the clinker "	203.091	"
From the soot "	23.105	"
Total	547.634	"

This is 14.28 per cent. of the coal consumed, proving that the first specimen analyzed was possessed of considerably less impurity than the average of the sample, and the second of nearly three times as much as its average proportion. In fact, specimen *b* is a highly bituminous slate, of which no small quantity occurred in the sample, showing a want either of skill or of proper care in the mining.

The clinker of this coal is much vitrified; the surface reddish brown; the interior, when broken, black; masses of considerable magnitude occur, with much shaly matter, variously colored, light, and porous. The clinker weighed 29.87 pounds per cubic foot, the ashes 40.92, and the soot 25.51 pounds.

From specimen *a* the composition is as follows, viz:

Moisture	0.957
Other volatile matter	26.103
Earthy matter	8.720
Fixed carbon	64.220
	100.

The volatile is to the fixed combustible as 1 : 2.46.

From the results of operations at the furnace, we have—

Moisture	1.785
Earthy matter	14.280
Combustible matter	83.935
	100.

If we grant that the four analyses above made give the true proportion of gaseous combustible, the average of the fixed carbon will be 83.935—23.959—59.976; and the volatile to the fixed combustible matter as 1 : 2.499. Twenty grains of specimen *b*, treated with 1,200 grains of oxide of lead, reduced 393.9 grains, or 19.695 times its own weight of metallic lead. A repetition of the experiment gave 19.54 times its weight.

In the anchor shop this coal produced a good hollow fire, worked well, but gave a rather large amount of cinder. The pieces of work were not of such magnitude as to require a large fire; hence, the full exhibition of its power to sustain the hollow condition of the fire was not probably called forth.

In the chain shop, 80 pounds proved sufficient to put in 9 links of 1½ inch chain. The cinder was abundant; the flame much like that of the Midlothian coal. In this shop there is no necessity of producing a hollow fire, the ends of the links being heated in close proximity with the tuyere.

In an office grate the ignition was rather tardy, owing to the fineness

of the coal; but, when once ignited, the coke cohered, and a brisk, cheerful blaze was emitted, exhibiting rather less brilliant jets of flame than some others of the Virginia coals.

The time required to bring the boiler to a uniform rate of action was as follows:

	h.	m.
First trial - - - - - -	1	10
Second trial - - - - - -	1	15
Third trial - - - - - -	1	00
Fourth trial - - - - - -	1	13

or the mean time was 1.158 hour.

The quantity of unburnt coke was, on an average, exactly six pounds. The pulverized and recalcined clinker is of a dark reddish-gray color, the ashes lighter, and the residue of the soot still lighter than that of the ashes.

In coking, this coal emits a red smoky flame, loses every trace of its original form, swells very much, and leaves a mass jet black, shining, and friable. This is the result of a rapid application of heat. When put into a muffle perfectly cold, of which the temperature was very gradually raised to ignition, scarcely any cohesion of particles was produced.

TABLE CVIII.—CROUCH

First trial—upper damper 12 inches

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
	4.40	64	56	108	120	64	198	-	29.70	-	-	0.15	-	-
	5.15	64	57	108	136	64	194	-	29.70	-	-	0.20	-	-
May 31	6 25	62	53	102	204	64	204	-	29.73	-	-	0.26	-	-
	7.15	61	53	100	224	64	224	-	29.75	0.193	8.66	0.28	-	-
	7.25	61	52.5	107	228	64	226	-	29.75	0.230	8 28	0.29	-	110.50
	8.00	63	54.5	114	250	64	226	-	29.77	0.218	8.40	0.35	170	-
	8.25	62.5	53.5	118	268	64	227	-	29.77	0.232	8.35	0.37	420	109.00
	9.00	61.5	52	132	302	64	228	-	29.77	0.245	8.14	0.41	845	-
	9.30	61	51	140	306	64	228	-	29.79	0.220	8.39	0 37	1415	108.25
	10.00	61	51	150	292	64	227	-	29.80	0.217	8.42	0.40	1715	-
	10.30	61	50.5	158	278	64	226	-	29.80	0.224	8.34	0.45	1900	-
	11.00	61	51	166	298	64	227	-	29.80	0.232	8.26	0.43	2115	107.25
	11.30	62	52	172	296	64	227	-	29.82	0.224	8.34	0.41	2485	-
	P. M.													
	0.00	61	51	183	310	64	228	-	29.82	0.240	8.19	0.40	2915	112.25
	0.30	61.5	51	186	310	63	227	-	29.82	0.234	8.24	0.41	3235	-
	1.00	64	53.5	194	319	63	229	-	29.82	0.236	8.20	0.42	3730	111.00
	1.40	62	51	198	316	63	229	-	29.82	0.236	8.20	0.40	4330	-
	2.05	62.5	51	208	312	60	227	-	29.82	0.228	8.30	0.40	4665	112.75
	2.30	62.5	51.5	211	318	60	228	-	29.82	0.234	8.24	0.40	4885	-
	3.30	62	51	218	308	65	226	-	29.83	0.228	8.30	0.38	5675	106.75
	4.00	62	50.5	224	304	65	228	-	29.83	0.234	8.24	0.39	6095	106.75
	4.45	63	50.5	225	294	65	228	-	29.82	0,220	8.39	0.36	6600	-
	5.05	63	51	230	288	65	228	-	29.83	0.224	8.34	0.42	6775	-
	5.30	63	52	229	320	65	228	-	29.82	0.234	8.24	0.41	6995	106.00
	6.00	64.5	53	235	282	65	226	-	29.83	0.196	8.62	0.34	7490	-
	6.30	-	-	-	-	65	-	-	-	-	-	-	8045	-
	A. M.													
June 1	4.45	55	46.5	170	178	62	208	-	29.92	-	-	0.20	8049	-

Period of steady action, from 9*h.* 45*m.* a. m. to 5*h.* 30*m.* p. m. — 7*h.* 45*m.*; coal supplied to grate, 762.75 pounds; water to boiler, 5,430 pounds; and water to one of coal, 7.119. The rate of steady action might, perhaps, with nearly equal propriety, be assumed to commence at 8*h.* 25*m.* a. m., when the second charge had all been placed on the grate.

& SNEAD'S COAL.

open; coking plate on; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 10.82 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet; a steam pipe extending up the chimney to within three feet of top of brick work.
h. m.					On the 30th of May a sheet-iron pipe, 22 feet 0½ inch high, was placed on chimney, making its whole height 63 feet.
-	49	44	—78		
-	51.2	44	—58	-	Commenced firing.
-	43.7	40	± 0		
-	44.7	39	0	-	Wood consumed, 188 pounds; steam at equilibrium; commenced charging with coal, with second weight on valve.
7.25	43.0	46	+ 2	-	Second weight removed from valve; steam blows off.
-	46	51	24	0.772	
8.25	44	55.5	41	1.589	Air plates opened.
-	43	70.5	74	1.929	Smoke 16.5 seconds in reaching chimney top.
9.45	39.4	79	78	3.012	
-	39.4	89	65	1.589	Drew 135 cubic inches of gases, which gave 0.64 grain water; potash and phosphorus not ready.
-	37.5	97	52	0.980	Drew 137 cubic inches of gases, which gave 0.5 grain water. Probably much air escapes combustion.
11.00	39.4	105	71	1.139	
-	41.1	110	69	1.960	
0.00	39.4	122	82	2.278	Smoke 15 seconds in reaching chimney top.
-	41	124.5	83	1.695	Smoke again 15 seconds in reaching chimney top.
1.00	43	130	90	2.622	Smoke still 15 seconds in reaching chimney top.
-	38.3	136	87	2.384	
2.05	40	145.5	85	2.129	Placed 28 pounds of this coal in drying apparatus.
-	39	148.5	90	1.899	Filled tank at 3*h.* p. m.
3.00	38.3	156	82	2.093	
4.15	36.5	162	76	2.225	
-	35.5	162	66	1.783	Drew 134 cubic inches of gases, which gave 1.04 grain water.
-	37.1	167	60	1.391	Dew point, by observation, 38°.
5.30	40.1	166	92	1.399	
-	40.7	170.5	56	2.622	Contents of ash pit thrown on grate; damper set at 6 inches.
-	-	-	-	-	Water in boiler left 1.4 inch above normal level; air plates closed.
-	38.4	115	—90	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	56.00
Ashes	87.00
Ashes and clinker behind grate	7.80
Total clinker and ashes	150.80
Deduct wood ashes	0.577
Total waste from coal	150.223
Coke	4.15

TABLE CIX.—CROUCH

Second trial—upper damper 6 inches open;

Period of steady action, from 9h. 20m. a. m. to 3h. 20m. p. m.=6h.; coal supplied to the grate, 647.85 lbs.; water to boiler in the same time, 4,610 lbs.; hence, water to 1 of coal for this period, 7.131.

& SNEAD'S COAL.

king plate on; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 13.39 square feet; length of circuit of heated gases 121 feet; height of chimney 68 feet; coking plate 11¾ inches wide.
h. m.					
-	31.3	115	—36	-	Commenced firing.
6.45	31.8	97	-	-	Wood consumed, 132 lbs.; steam at equilibrium; commenced charging with coal.
7.00	31.3	102	-	-	Steam blows off.
	……	……			
-	31.0	102.5	+17	0.906	
-	31.8	103	53	1.325	Smoke 18 seconds in reaching chimney top; syphon 0.38.
-	35.5	105	76	2.225	Small furnace damper closed; smoke 19 seconds in reaching chimney top; syphon 0.35.
-	32.1	112	82	1.669	
9.30	-	-	-	-	Filled tank; smoke 21 seconds in reaching chimney top; syphon 0.36.
……			……	……	
10.00	34.6	130	73	1.854	
-	34.6	134	82	1.351	Smoke 21 seconds in reaching chimney top; syphon 0.36.
-	32.6	141	86	2.225	
11.30	33.6	148.5	88	2.172	Extra weight removed from back valve; draught is thereby reduced, as seen in the column for syphon.
-	41.1	152	84	1.828	
0.20	37.1	162	80	1.801	
1.30	42.4	169	83	2.305	
2.15	40.7	179	79	2.198	During this experiment, the weather clear; wind NW., brisk.
3.30	46.1	187	96	2.039	Filled tank at 3*h.* 20*m.*; smoke 18 seconds in reaching chimney top; syphon 0.38.
……	……	……	……	……	
-	42.4	190	95	3.046	Contents of ash pit thrown on grate.
-	32.7	200	53	1.351	Water in boiler left at 0.9 inch above normal level.
-	34.7	132	—29	-	Water in boiler found at 0.7 inch below normal level.
-	34.7	181	—30	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	52.75
Ashes - - - - - - - - - - -	76.625
Ashes and clinker behind bridge - - - - - - -	7.04
	136.415
Deduct wood ashes - - - - - - - - -	0.405
Total waste from coal - - - - - - - -	136.010
Coke - - - - - - - - - - -	4.38

TABLE CX.—CROUCH

Third trial—lower damper 6 inches open;

												phon.	Weight of water supplied to boiler.	Weight of charges of coal.
June 2	5.08	44	41	175	171	64	201	-	[illegible]	-	-	0.20	-	-
	6.30	50	46.5	156	-	[illegible]	226	-	30.26	0.202	[illegible]	0.25	-	105.50
	7.00	56	49	[illegible]	440	[illegible]	[illegible]	-	30.26	0.223	[illegible]	0.37	-	[illegible]
	7.30	57	50	168	512	65	227	-	30.26	0 233	8.25	0.36	277	-
	8.00	60.5	52	168	-	65	228	-	30.28	0.247	8.10	[illegible]	697	-
	8.30	61.5	52	176	-	65	228	-	30.28	0.237	8.21	0.36	[illegible]	108.50
	[illegible]	[illegible]	50	180	-	65	228	-	30 28	0 243	8.16	0.40	1197	-
	[illegible]	62.5	51.5	185	-	64	228	-	30.28	[illegible]	8.18	0.39	1772	106.25
	10.00	62	51	192	-	61	228	-	30.28	0.234	8.28	[illegible]	2187	-
	10.45	63	51	201	-	[illegible]	228	-	30.26	0.238	[illegible]	0.40	2647	[illegible]
	11.10	63	53	[illegible]	-	62	[illegible]	-	20.25	0.233	8.24	0,39	[illegible]	-
	11.30	64	53	206	-	[illegible]	[illegible]	-	30.24	0.226	8.32	[illegible]	3307	106.75
	P. M.													
	0.00	65	54	210	-	62	226	-	30.22	0.226	8.32	0.38	3642	-
	0.35	66	[illegible]	213	-	[illegible]	227	-	30.22	[illegible]	[illegible]	0.41	[illegible]	-
	1.15	67	56	217	-	63	227	-	30.19	0.230	8.27	[illegible]	4417	104.75
	1.55	68.5	[illegible]	220	-	63	[illegible]	-	30.16	0.227	8 31	[illegible]	4997	[illegible]
	2.35	68.5	56	220	-	63	[illegible]	-	30.14	0.208	8.50	0.36	5157	-
	3.05	-	-	-	-	-	-	-	-	-	-	-	5492	-
	A. M.													
June 3	4.20	66	61	197	166	[illegible]	204	-	29.95	-	-	0.14	5497	-
	4.40	66	61	196	166	[illegible]	[illegible]	-	29.95	-	-	0.14	5739	-

From 8*h*. 30*m*. a. m. to 1*h*. 55*m*. p. m. = 5*h*. 25*m*., is the assumed period of steady action. Coal supplied to the grate, 530 lbs.; water to the boiler, 3,966 lbs.; water to 1 of coal, for the same period, 7.487.

& SNEAD'S COAL.

coking plate and air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 59.5 feet; height of chimney 63 feet.
h. m.					
-	34.7	131	— 30	-	Commenced firing.
6.30	38.0	108	-	-	Wood consumed, 161½ lbs.; steam at equilibrium; commenced charging; steam blows off at 6*h.* 50*m.* a. m.; lower damper set at 6 inches at 7*h.* 15*m.* a. m.
7.00	39.8	104	+214		
-	41.4	111	285	1.916	Smoke 13 seconds in reaching chimney top; syphon 0.38.
-	42.0	107.5	-	2.906	Wooden support of thermometer in the escaping gases took fire, causing the instrument to burst; the mean temperature is assumed to be that of the last recorded observation, 512°.
8.30	40.8	114.5	-	2.297	
-	36.4	119	-	1.162	
9.30	39.2	122.5	-	3.955	
-	37.1	129	-	2.872	Smoke 12 seconds in reaching chimney top; syphon 0.40.
10.30	37.1	138	-	2.122	Filled tank at 10*h.* 50*m.* a. m.
-	42.7	143	-	2.823	
11.30	41.7	142	-	3.322	Smoke 13 seconds in reaching chimney top; syphon 0.38.
-	43.4	145	-	2.318	
-	45.0	147	-	1.513	Smoke 13 seconds in reaching chimney top; syphon 0.40.
0.45	46.5	150	-	2.647	
1.55	46.5	151.5	-	2.543	
-	46.0	161.5	-	1.799	Contents of ash pit thrown on grate; wind all day from W. to SW.; clear.
-	-	-	-	-	Water in boiler left at 0.45 inch above normal level.
-	57.5	131	— 38	-	Water 0.6 inch below normal level.
-	57.5	131	— 30	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	36.75
Ashes	83.50
Ashes and clinker behind bridge	6.20
	126.45
Deduct wood ashes	0.495
Total waste from coal	125.955
Coke	11.60

TABLE CXI.—CROUCH

Fourth trial—upper damper 6 inches open; air plates

Period of steady action, from 9*h*. a. m. to 5*h*. 30*m*. p. m. = 8*h*. 30*m*. Coal supplied to grate, 743.5 lbs: water to boiler, 5,917 lbs.; and water to 1 of coal, 7.959.

SNEAD'S COAL.

open; coking plate off; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	57.5	131	— 32	-	Water at normal level in boiler.
-	58.7	108	— 47	-	Commenced firing.
8.17	62.8	100	+ 23	-	Wood consumed, 160½ lbs.; steam at equilibrium; commenced charging with coal.
-	61.9	98	— 11	-	Steam blowing off; wind SW., brisk; clear.
9.00	62.3	93	+ 54	0.864	Air plates opened; upper damper set at 6 inches; a small portion of mercury in the upper portion of the thermometer in boiler discovered, and rejoined to the rest. Drew
....	....	....	....	....	
-	61.8	97	74	2.198	
-	62.4	101.5	82	0.450	134 cubic in. of gases, which gave 1.10 grain of water.
10.30	63.8	109	85	1.351	Wind boisterous, SW.; no smoke reaching chimney top; filled tank at 11*h*. 0*m*. a. m.
-	62.5	116	92	1.825	Drew 132 cubic inches of gases at 10*h*. 45*m*., which gave
11.40	63.7	121	90	3.401	1.14 grain of water, and 5.614 grains of carbonic acid.
-	63.3	126	96	1.261	Sky overcast; wind SW., moderate; coal falls rapidly through grate, being very fine.
-	62.8	133	90	0.907	Smoke 18 seconds in reaching chimney top at 0*h*. 10*m*. p. m.
1.00	65.3	135	86	2.675	Smoke 20 seconds in reaching chimney top at 0*h*. 45*m*.;
-	65.7	138	88	1.377	at 0*h*. 50*m*. it was 20″.5; at 1*h*. 0*m*. 19″.5; tried again,
2.05	64.9	145	95	2.262	it was 20″.5; clouding up, with thunder; wind SW., brisk;
-	65.3	154	82	1.828	at 2*h*. 30*m*. p. m. smoke 24 seconds in reaching chimney top; syphon 0.23.
3.00	67.2	162	89	1.208	Commenced raining at 3*h*. 20*m*. p. m.
-	66.5	168	94	2.596	Temperature of open air 69°.
4.00	65.0	176	79	1.775	Ceased raining; wind SW.
-	66.5	178	78	1.325	Coal in drying apparatus weighs 27 lbs. 8 oz.
-	66.9	182	86	2.236	Filled tank; smoke 20 seconds in reaching chimney top; syphon 0.26.
5.30	66.5	178	92	2.622	
....	....	....	....	....	
-	66.9	186	76	1.841	Air plates closed; contents of ash pit on grate; water left 0.7 inch above normal level at 6*h*. p. m.
-	58.4	132.5	— 34	-	Water 1.15 inch below normal level.
-	60.5	133	— 34	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	59.00
Ashes	71.25
Ashes behind bridge	6.96
Total of clinker and ashes	137.21
Deduct wood ashes	0.492
Total waste from coal	136.718
Coke	3.87
Soot	34.75

TABLE CXII.—DEDUCTIONS

Experiments on Crouch

	Nature of the data furnished by the respective tables.	1st Trial. (*Table CVIII.*)	2d Trial. (*Table CIX.*)
		May 31.	*June* 1.
1	Total duration of the experiment, in hours	24 081	23.417
2	Duration of steady action, in hours	7.75	6.0
3	Area of grate, in square feet	10.82	13.39
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	14.4189	17.42
6	Number of charges of coal supplied to grate	10.0	9.0
7	Total weight of coal supplied to grate, in pounds	1090.5	967.75
8	Pounds of coal actually consumed	1086.35	963.37
9	Pounds of coal withdrawn and separated after trial	4.15	4.38
10	Mean weight, in pounds, of one cubic foot of coal	54.525	53.764
11	Pounds of coal supplied per hour, during steady action	98.419	107.875
12	Pounds of coal per square foot of grate surface, per hour	9.091	8.056
13	Total waste, ashes and clinker, from 100 pounds of coal	13.828	14.117
14	Pounds of clinker alone, from 100 pounds of coal	5.2101	5.5379
15	Ratio of clinker to the total waste, per cent.	37.675	39.225
16	Total pounds of water supplied to the boiler	8049.0	7294.0
17	Mean temperature of water, in degrees Fahrenheit	64°.3	63°.1
18	Pounds of water supplied at the end of experiment, to restore level	4.0	258.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	0.0	35.0
20	Pounds of water evaporated per hour, during steady action	700.645	768.33
21	Cubic feet of water per hour, during steady action	11.21	12.29
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.856	2.035
23	Pounds of water per sq. foot, by a mean of several observations	1.804	1.975
24	Water evap. by 1 of coal, from initial temp, (a) final result	7.409	7.535
25	Water evaporated by 1 of coal, from initial temperature, (b) during steady action	7.119	7.131
26	Pounds of fuel evaporating one cubic foot of water	8.4357	8.2946
27	Mean temperature of air entering below ash pit, during steady pressure	62°.08	60°.23
28	Mean temp. of wet bulb thermom., during steady pressure	51°.55	49°.65
29	Mean temperature of air, on arriving at the grate	181°.9	200°.61
30	Mean temperature of gases, when arriving at the chimney	299°.42	302°.08
31	Mean temperature of steam in the boiler	227°.47	226°.77
32	Mean temperature of attached thermometer	60°.0	56°.0
33	Mean height of barometer, in inches	29.809	30.089
34	Mean number of volumes of air in manometer	8.291	8.287
35	Mean height of mercury in manometer, in atmospheres	0.229	0.229
36	Mean height of water in syphon draught gauge, in inches	0.4053	0.3533
37	Mean temperature of dew point, by calculation	39°.9	36°.40
38	Mean gain of temperature by the air before reaching grate	119°.82	140°.38
39	Mean difference between steam and escaping gases	76°.61	83°.44
40	Water to 1 of coal, corrected for temp. of water in cistern and boiler	7.4276	7.509
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern and boiler	8.4949	8.5958
42	Pounds of water, from 212°, to 1 cubic foot of coal	463.19	464.48
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	9.8581	10.0082
44	Mean pressure, in atmospheres, above a vacuum	1.4072	1.4163
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.0158	6.1476
46	Condition of the air plates at the furnace bridge	Open.	Removed.
47	Inches opening of damper, (U. upper, L. lower)	U. 12	U. 6

FROM TABLES CVIII, CIX, CX, CXI.

& Snead's coal.

3d Trial. (*Table CX.*)	4th Trial. (*Table CXI.*)	Averages.	Remarks.
June 2.	*June 3.*		
23.533	27.0		
5.417	8.50		
16.25	16.25		
287.0	377.5	–	On the 3d trial, the products of combustion passed into the chimney through the lower damper, and, consequently, without making the circuit round the boiler by way of the external flue.
21.65	21.65		
8.0	9.0		
846.0	954.5		
834.40	950.63		
11.60	3.87	6.0	
52.875	53.027	53.548	
97.84	87.47	97.901	On the day of the 2d trial, when the combustion was most rapid, a brisk northwest wind prevailed.
6.002	5.382	7.133	
15.036	14.381	14.3405	
4.4751	6.2613	5.3711	
29.655	4[illegible].534	37.522	
5739.0	712[illegible].0		
62°.9	67°.0		
252.0	552.0		
35.0	75.0		
732.54	696.119	724.408	
11.72	11.376	11.649	
2.552	1.8423	2.0713	
2.5277	1.841		
6.836	7.413	7.298	
7.487	7.959	7.421	
9.1427	8.4311	8.576	
63°.23	78°.27		
52°.7	68°.94		
195°.54	220°.59	199°.66	
512°.0?	319°.12	306°.873	The last observed temperature, on the 3d trial, is the one assumed for that of steady action, though it is not doubted that the temperature, during some parts of the day, rose higher than the point of 512°. As the gases had already passed nearly 60 feet in contact with the boiler and flues, it had traversed a longer course than is often given to the flues on board of steam ships. The latter frequently make their chimneys red hot, or about 1100°.
227°.23	232°.18		
61°.0	75°.0		
30.248	29.889		
8.234	8.455		
0.234	0.2122		
0.394	0.2853	0.3595	
41°.52	64°.71		
132°.31	142°.32	133°.71	
284°.77?	87°.06	81°.78	
6.8181	7.4375	7.298	
7.8044	8.4845	8.3448	
412.50	449.91	445.02	
9.1855	9.9096	9.7403	In the 3d trial, the evaporative efficiency of the pound of combustible matter appears to have been affected by the burning with the lower damper open, and the escape of the products of combustion at a temperature of 512°, (as seen in line 30,) instead of about 307°, the mean temperature at which i escaped in the other three trials.
1.4239	1.4122	1.4174	
6.4087	6.0874	6.1649	
Removed.	Open.		
L. 6	U. 6		

No. 3.

Bituminous coal from the mines of the Midlothian Coal Company, taken from a shaft 900 feet deep.

This sample was not accompanied by any written description, except the labels on the casks, which indicated the origin above described.

It is externally characterized by a lustre, either dull, resinous, or shining, according to the faces which are observed. The main partings, at right angles to the surfaces of deposition, are usually shining; those surfaces themselves are dull or resinous, but polished portions sometimes occur, giving the impression of having been rendered smooth by intense pressure and a sliding motion.

In the parting seams, thin plies of carbonate and of sulphate of lime frequently occur.

The specific gravity of two specimens of this coal which I analyzed was for *a*, by two trials, 1.511; and for *b*, 1.2889—the former giving for the weight of a cubic foot of solid coal in the mine 94.435, and the latter 80.662 pounds.

By the mean of 34 trials in the charge box, the weight of a cubic foot, in the state in which it was received, was 50.518 pounds; the highest being 53.375, and the lowest 48.375; of which two, the mean is 51.375: so that the actual is but 0.5349 of the first calculated weight, and 0.6263 of the second.

The space required for the stowage of a ton is 44.341 cubic feet.

In the steaming apparatus, 28 pounds lost 5¼ ounces, or 1.1719 per cent. of moisture.

The volatile matter, including moisture, in specimen *a* was 27.06, and that in *b* 29.84 per cent.

The ashes of *a* are 21.25 per cent., of a chocolate-brown color; and those of *b* 6.08 per cent., of a reddish gray.

Bringing together these results, we find them as follows:

	Specimen *a*.	Specimen *b*.
Specific gravity - - - - -	1.511	1.2889
Moisture - - - - -	1.1719	1.1719
Other volatile matter - - -	25.8881	28.6681
Earthy matter - - - -	21.2500	6.0800
Fixed carbon - - - - -	51.6900	64.0800
	100.	100.
Volatile to fixed combustible -	1 : 1.996	1 : 2.235

During three trials on evaporation, the quantity of coal actually consumed was 3,417.5 pounds; and the amount of *ashes* yielded was 143.75 pounds, weighing 53.51 pounds per cubic foot; of *clinker* 221.75 pounds, weighing 43.37 pounds per cubic foot; and 14.2 pounds of *soot*, of which 5.74 pounds made a cubic foot.

The clinker is in lumps of a large size, black, and porous, with some tendency to spread into sheets, tenacious and compact, embracing but little light-colored shaly matter.

By complete reduction of the combustible matter of these three residua, the

Ashes	lost 9.687	per cent.,	leaving	129.82 pounds.
Clinker	" 0.000	"	"	221.75 "
Soot	" 56.630	"	"	6.13 "
Total absolutely incombustible matter				=357.70 "

And this is 10.467 per cent. of the coal burned.

Hence the sample was composed of—

Moisture (from 28 pounds) - - - - -	1.1719 per cent.
Other volatile matter (from mean of two specimens) -	27.2781 "
Earthy matter (from 3,417.5 pounds) - - -	10.4670 "
Fixed carbon (calculated by difference) - -	61.0830 "
	100.

Hence the volatile is to the fixed combustible 1 : 2.239

The reincinerated or calcined clinker produced a light brown powder, gaining slightly in weight by the treatment.

The ashes gave a reddish gray residue, and the soot one of a dark fawn color.

Twenty grains of specimen *b*, with the oxide of lead, yielded 500.7 grains of metallic lead, equal to 25.035 times its own weight. Deducting the moisture and earthy matter, (7.252 per cent.,) the lead to 1 of *combustible* is 26.993.

In the chain shop, 60 pounds were sufficient to put in 8 links of a chain $1\frac{1}{4}$-inch in diameter. In the common smith work of the anchor shop, it was observed to produce a fair hollow fire; gave a clear white, but short flame; affording a good heat for welding iron and steel together, which was the work in hand at the time the trial was made.

The sample was in rather too fine a state for use in an office grate, but by a little management it gave a brilliant and active fire. After the coal has become well heated, brilliant jets of flame are frequently emitted.

The coke is of a coherent intumescent character, occupying considerably more space than the coal from which it was formed.

The average time required by this coal to bring the boiler into uniform action, was 1.383 hour.

The average weight of unburnt coke was 5.917 pounds.

By reference to the table of deductions, it will be observed that the proportion of *clinker* to the *total waste* derived from this coal was more than 60 per cent.; which might readily indicate the probability of its offering considerable obstruction to the combustion, especially after a few hours' operation. Such was the fact; masses or plates 15 or 18 inches in diameter were drawn out.

When not impeded by an accumulation of clinker, the combustion is free, with a large red smoky flame. The clinker has some tendency to adhere to the grate bars, and keep them at a cherry-red heat, which induces warping and displacement.

TABLE CXIII.—MIDLOTHIAN

First trial—upper damper 8 inches open; air plates open;

Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
0.15	-	-
0.20	-	-
0.28	-	[illegible]
0.27	-	98.00
0.30	60	-
0.45	[illegible]	99.00
[illegible]	1080	-
0.38	1563	-
0.36	[illegible]	96.75
0.35	2420	97.75
0.33	2936	101.50
0.32	3800	99.00
0.36	4407	99.75
0.38	4827	-
0.37	[illegible]	100.75
[illegible]	5972	97.50
0.36	6498	-
0.40	6878	101.25
0.40	7383	-
0.40	7926	[illegible]
0.30	8256	-
0.31	8873	-
0.30	9110	-
0.24	9110	-
0.20	9184	-

Period of steady action, from 7*h.* 54*m.* a. m. to 3*h.* 10*m.* p. m.=7*h.* 16*m.*; coal supplied to the grate, 892.25 lbs.; water to the boiler, 7,233 lbs.; water to 1 of coal, 8.106.

(900 FEET SHAFT) COAL.

steam thrown out at both valves, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	45 2	85	—36	-	Water brought to 0.2 inch below normal level; lighted fire at 4*h.* 27*m.* a. m.
-	45 2	71	+ 7	-	Valves double weighted; small furnace lighted at 5*h.* 42*m.*; water at normal level at 212°.
6.11	45.0	72	—15	-	Wood consumed, 149½ lbs.; commenced charging with coal; wind NW., brisk; clear.
6.45	43 8	70	—13	-	Steam allowed to escape from front valve by removing second weight; water 0.28 inch above normal level.
-	42.4	74	+ 8	0.318	Air plates opened at 7*h.* 10*m.*
7.54	42.4	81	54	1.791	Second weight removed from back valve, to prevent any intermixture of water with the escaping steam.
-	48.8	93	67	3.613	
-	50.0	111	78	2.559	
9.00	51.2	127	77	2.262	
9.37	51.5	142	72	2.278	Wind W., brisk; clear.
10.15	49.8	150	79	2.734	
11.02	50.4	156	83	3.518	Placed 28 lbs. of this coal in kettle to dry.
11.40	51.0	173	93	2.332	Filled tank at 11*h.* 25*m.*
-	52.3	184	85	2.225	
0.37	51 6	195	79	3 088	
1.20	51.0	202	88	2.490	
-	52.4	209	103	2.760	Filled tank; removed from grate a quantity of clinker in large sheets, which had much impeded combustion; grate bars cherry red.
2.13	50.3	215	115	2.013	
-	52.4	218	107	2.675	
3.10	49.6	221	108	2.877	
-	50.3	237	101	1.748	Air plates closed, and contents of ash pit thrown on grate.
-	45.7	233	69	2.209	Clear day; wind NW., brisk.
-	45.7	232	63	4.680	Damper set at 2 inches; water 0.9 inch above normal level.
-	47.6	186	—20	-	Water left at 0.19 inch above normal level.
-	48.8	138	—32	-	Water in boiler adjusted for temperature.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	78.00
Ashes - - - - - - - - - - -	40.00
Ashes behind bridge - - - - - - - - - -	4.50
	122.50
Deduct wood ashes - - - - - - - - - -	0.458
Total waste from coal - - - - - - - -	122.042
Coke - - - - - - - - - - -	5.86

TABLE CXIV.—MIDLOTHIAN

Second trial—upper damper 8 inches open; air

Date.	Hour.	TEMPERATURES OF THE							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of coal supplied to grate at each time.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m.													
	A. M.													
Oct. 11	6.33	51	50	189	183	63	215	55	29.92	0.386	6.69	0.20	-	-
	7.25	52.5	50	167	246	63	231	54.5	29.93	0.565	4.93	0.28	-	102.50
	7.50	53	51	166	245	63	232	55	29.94	0.583	4.75	0.30	-	106.75
	8.30	56	53	170	317	63	232	55	29.94	0.560	4.98	0.40	254	-
	9.00	60	55	178	333	63	231	56	29.94	0.548	5.10	0.36	730	102.25
	9.30	62	56	195	334	63	231	58	29.94	0.548	5.10	0.36	1154	-
	10.00	62	57	216	336	63	233	60	29.96	0.551	5.06	0.35	1480	103.00
	10.45	64	57	233	345	63	233	61	29.95	0.550	5.08	0.36	2045	-
	11.15	67	59	248	341	60	233	62	29.94	0.541	5.16	0.35	2615	102.50
	11.45	68	60	254	345	60	234	64	29.94	0.550	5.07	0.35	3117	-
	P. M.													
	0.15	71	62	261	356	60	234	65	29.94	0.548	5.10	0.35	3367	99.50
	0.45	71	62	265	351	60	234	66	29.93	0.541	5.16	0.34	3877	-
	1.15	75	64	277	334	60	233	67	29.93	0.548	5.10	0.32	4547	99.50
	1.45	77	65	284	335	60	233	69	29.93	0.537	5.20	0.31	4937	102.00
	2.30	79	66	296	358	60	233	70	29.93	0.545	5.12	0.32	5421	96.75
	3.15	77	65	306	358	65	233	71	29.93	0.545	5.12	0.34	6277	-
	3.45	78	65	310	366	65	234	71	29.93	0.550	5.07	0.31	6565	101.75
	4.20	78	64	316	363	65	234	71	29.93	0.553	5.04	0.32	7153	104.25
	4.45	76	64	322	362	65	234	71	29.93	0.540	5.17	0.32	7711	-
	5.05	75	62	330	322	65	233	71	29.92	0.533	5.24	0.30	8105	-
	6.05	67	59	328	278	65	232	69	29.92	0.523	5.34	0.28	8270	-
	8.50	68	60	319	223	65	230	66	29.94	0.500	5.56	0.25	8435	-
	A. M.													
Oct. 12	5.05	58	55	240	196	65	224	60	29.86	0.468	5.86	0 21	8437	-
	5.30	57	55	236	195	65	222.5	59.5	29.86	0.453	6.02	0.20	8537	-

Period of steady action, from 8*h.* 56*m.* a. m. to 3*h.* 55*m.* p. m.=6*h.* 59*m.* Coal supplied to grate, 809.25 lbs.; water supplied to boiler, 6,066.47 lbs.; water to 1 of coal for that space of time, 7.496.

(900 FEET SHAFT) COAL.

plates closed; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	48.8	138	—32	-	Morning clear; wind E., light; commenced firing; water 0.06 inch below normal level.
7.25	46.8	114.5	+15	-	Wood consumed, 104¼ lbs.; commenced charging with coal; water 0.2 inch above normal level.
7.50	48.6	113	•12	-	Second weight removed from front valve; steam blows off.
-	49.8	114	85	1.009	Steam allowed to escape from back valve.
8.56	50.3	118	102	2.522	
-	50.7	133	103	2.246	
10.04	52.8	154	103	1.727	Wind SW., light; clear.
-	51.2	169	112	1.996	Filled tank at 10*h.* 58*m.* a. m.
11.00	53.0	181	108	3.019	
-	54.3	186	111	2.659	
11.59	56.2	190	121	1.324	
-	56.2	194	117	2.702	
0.48	57.7	202	101	3.549	
2.00	58.5	207	102	2.066	Clinker removed, being heavy and dark colored, and spreading over the grate, to which it adheres slightly, tending to heat the bars and impede combustion; filled tank at 3*h.* 8*m.* p. m.
2.30	59.4	217	125	1.709	
-	58.5	229	125	3.023	
3.19	58.1	232	132	1.526	Grate bars cherry red; much smoke from chimney to-day.
3.55	56.2	238	129	2.670	
-	57.2	246	128	3.548	Contents of ash pit thrown on grate; damper set at 4 inches.
-	54.0	255	89	3.131	Water left at 0.7 inch above normal level.
-	53.0	261	46	0 437	Water now 0.15 inch above normal level.
-	54.3	251	— 7	0.159	Double weighted safety valves; closed damper and air port.
-	52 2	182	—28		
-	53.1	179	—27.5	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	66.75
Ashes	45.75
Ashes behind bridge	4.25
Total ashes and clinker	116.75
Deduct wood ashes	0.32
Total waste from coal	116.43
Coke	7.32

TABLE CXV.—MIDLOTHIAN

Third trial—upper damper 8 inches open; air plates open; steam

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Oct. 12	6.40	57	55	225	194	65	232	58	29.86	0.439	6.15	0.19	-	-
	7.00	57	55	211	312	65	228.5	58	29.86	0.556	5.02	0.32	-	104.25
	7.35	62	58	208	310	65	232	58	29.87	0.542	5.14	0.31	182	98.25
	8 00	64	59	202	302	65	232	59	29.87	0.545	5.12	0.35	508	-
	8.30	70	63	213	317	62	233	59	29.89	0.537	5 20	0.31	508	-
	9.00	69	64	230	347	62	234	61	29.89	0.550	5.05	0.41	915	-
	9.30	70	64	252	352	62	233	63	29.89	0.547	5.10	0.36	1419	101.50
	10.00	78	67	264	366	62	233	65	29.89	0 543	5 14	0.38	1631	102.75
	10.30	70	65	275	366	62	232	67	29.91	0.546	5 11	0 38	2084	102.00
	11.00	72	65	282	371	62	232	69	29.91	0.542	5 15	0.38	2588	-
	11.30	72	64	296	355	62	233	70	29.91	0.542	5.15	0.33	2847	-
	P. M. 0.00	74	66	308	372	63	233	71	29.91	0.537	5.20	0.35	3306	102 25
	0.30	78	67	298	382	62	232	71	29.91	0.539	5 18	0.35	3827	101.75
	1.00	78	67	292	388	63	232	72	29.91	0.532	5 25	0.38	4162	-
	1.30	74	65	320	400	63	232	72	29.92	0.545	5.12	0.43	4418	101.00
	2.00	74	64	338	381	63	233	72	29.92	0.541	5 15	0.40	5090	105.50
	2.30	73	63	351	393	64	233	72	29.93	0.541	5.15	0.42	5470	-
	3.00	73	63	357	396	64	232	72	29.93	0.532	5.25	0.43	6125	102.25
	3.30	72	62	363	382	64	232	71	29.93	0.543	5.14	0 45	6530	-
	4.00	72	62	371	403	64	233	71	29.96	0.545	5.12	0.40	6853	105.75
	4.30	70	58	372	344	65	230	70	29.96	0.505	5.52	0.34	7407	-
	5.00	70	59	366	320	65	230	70	29.96	0.519	5 38	0.30	7696	-
	10.05	62	54	308	224	65	228	64	30.02	0.500	5 56	0.22	7890	-
Oct. 13	A. M. 6.10	52	48	240	194	64	222	56	30.03	0.448	6.07	0.22	7893	-
	6.30	50	47	234	193	64	220	56	30.06	0.440	6.16	0.22	7958	-

Period of steady action, from $9h.$ $9m$ a. m. to $3h.$ $36m.$ p. m. $= 6h.$ $27m.$ Coal to grate for that time, 823.25 lbs.; water to boiler, same period, 5,528.4 lbs.; water to 1 of coal, 6.715.

(900 FEET SHAFT) COAL.

thrown into chimney, small furnace in action, and ash pit doors open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	53.1	168	—28	-	Commenced firing; water 0.1 inch above normal level; wind W.; very light; hazy.
7.08	53.1	154	+83.5	-	Wood consumed, 72.5 lbs.; commenced charging with coal.
7.39	54.8	141	78	0.826	Steam escapes at 7*h.* 10*m.*; ash pit doors open.
-	55.2	138	70	-	Filling tank; wind SE., light; water 1 inch above normal level.
-	58.7	143	84	0.942	Tank filled; water at normal level.
-	61.0	161	113	2.156	Smoke 17 seconds in reaching chimney top; syphon 0.40 inch.
9.09	60.5	182	119	2.670	Commenced drawing gases at 9*h.* 51*m.*; drew in 51 minutes 100 cubic inches, which gave water 0.95 grain, carbonic acid 5.96 grains, oxygen 11.213 cubic inches; dew point, by observation, 61°.5; temperature of bath, 71°; closed air port below ash pit at 10*h.* 8*m.*
9.45	64.0	191	133	1.070	
10.54	62.2	205	134	2.400	
-	61.1	210	139	2.670	
-	59.3	224	122	1.372	Filled tank at 11*h.* 48*m.*
11.48	61.8	234	139	2.432	Commenced drawing gases second time (ash pit doors having been closed) at 0*h.* 17*m.* p. m.; drew in 37 minutes 100 cubic inches, which gave water 0.80 grain, carbonic acid 5.75 grains, oxygen 11.182 cubic inches; temperature 72°; ash pit doors opened at 1*h.* 0*m.* p. m.
0.37	61.6	220	150	2.760	
-	61.6	214	156	1.775	
1.20	60.1	246	168	1.356	During the drawing of gases on both occasions, the fire was in good action, with a good bed of coal on grate.
2.12	61.8	264	148	3.560	
-	57.0	278	160	2.013	
3.00	57.0	284	164	3.470	
-	55.7	291	150	2.146	Apparently less smoke from chimney to-day than yesterday.
3.36	55.7	299	170	1.711	Contents of ash pit thrown on grate at 4*h.* 25*m.*; damper set at 3 inches; filled tank.
-	48.8	302	114	2.935	Ash pit doors closed; air port open.
-	51.0	296	90	-	Water 0.8 inch above normal level.
-	46.2	246	— 4	-	Closed damper and air port; water 0.15 inch above normal level.
-	42.4	188	—28	-	Water found 0.1 inch below normal level.
-	42.6	184	—27	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	77.00
Ashes	46.00
Ashes from behind bridge	4.25
Total clinker and ashes	127.25
Deduct wood ashes	0.223
Total waste from coal	127.027
Coke	4.57
Soot	14.125

TABLE CXVI.—DEDUCTIONS

Experiments on Midlo

	Nature of the data furnished by the respective tables.	1st Trial. (Table CXIII.)	2d Trial. (Table CXIV.)
		October 10.	October 11.
1	Total duration of the experiment, in hours	26.55	22.917
2	Duration of steady action, in hours	7.267	6.983
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	12.0	11.0
7	Total weight of coal supplied to grate, in pounds	1187.25	1120.75
8	Pounds of coal actually consumed	1181.39	1113.43
9	Pounds of coal withdrawn and separated after trial	5.86	7.32
10	Mean weight, in pounds, of one cubic foot of coal	49.469	50.943
11	Pounds of coal supplied per hour, during steady action	122.798	115.888
12	Pounds of coal per square foot of grate surface, per hour	8.728	8.236
13	Total waste, ashes and clinker, from 100 pounds of coal	10.33	10.456
14	Pounds of clinker alone, from 100 pounds of coal	6.5747	5.9777
15	Ratio of clinker to the total waste, per cent.	63.663	57.166
16	Total pounds of water supplied to the boiler	9184.0	8537.0
17	Mean temperature of water, in degrees Fahrenheit	63°,0	62°.8
18	Pounds of water supplied at the end of experiment, to restore level	28.0	100.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	4.0	14.0
20	Pounds of water evaporated per hour, during steady action	995.458	868.748
21	Cubic feet of water per hour, during steady action	15.927	13.899
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.637	2.301
23	Pounds of water per square foot, by a mean of several observations	2.673	2.238
24	Water evaporated by 1 of coal, from initial temp. (a) final result	7.768	7.652
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	8.106	7.496
26	Pounds of fuel evaporating one cubic foot of water	8.0459	8.1678
27	Mean temp. of air entering below ash pit, during steady pressure	65°.07	71°.0
28	Mean temp. of wet bulb thermometer, during steady pressure	56°.87	61°.4
29	Mean temperature of air, on arriving at the grate	230°.2	264°.06
30	Mean temperature of gases, when arriving at the chimney	319°.0	347°.73
31	Mean temperature of steam in the boiler	233°.16	233°.13
32	Mean temperature of attached thermometer	60°.57	65°.47
33	Mean height of barometer, in inches	29.839	29.937
34	Mean number of volumes of air in manometer	5.078	5.11
35	Mean height of mercury in manometer, in atmospheres	0.5491	0.5463
36	Mean height of water in syphon draught gauge, in inches	0.3731	0.3385
37	Mean temperature of dew point, by calculation	50°.31	55°.35
38	Mean gain of temperature by the air, before reaching grate	165°.13	193°.06
39	Mean difference between steam and escaping gases	84°.5	113°.64
40	Water to 1 of coal, corrected for temp. of water in cistern	7.768	7.652
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	8.8917	8.759
42	Pounds of water, from 212°, to 1 cubic foot of coal	439.86	446.21
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	9.9161	9.7817
44	Mean pressure, in atmospheres, above a vacuum	1.423	1.4238
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.2469	6.2597
46	Condition of the air plates at the furnace bridge	Open.	Closed.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

FROM TABLES CXIII, CXIV, CXV.

thian (900 *feet shaft*) *coal.*

3d Trial. (Table CXV.)	Averages.	Remarks.
October 12.		The combustion was conducted, on the 3d day's trial, with the ash pit doors open. By the 40th, 41st, and 43d lines, below, this arrangement is seen to have given a result decidedly inferior to those obtained at the two previous experiments.
23.833		
6.45		
14.07		
377.5		
18.75		
11.0		
1127.25		
1122.68		
4.57	5.917	
51.238	50.55	
127 628	122.105	
9.071	8.6783	
11.32	10.702	
6.8468	6.4664	
60.512	60.447	
7958.0		
63°.0		
65.0		
9.0		
857.116	907.107	
13.714	14.513	
2.27	2.403	
2.243		
7.078	7.4993	
6.715	7.439	
8.8302	8.3479	
73°.21		
64°.57		
–	247°.13	
373°.1	348°.61	
232°.5		
69°.86		
29.916		
5.158		
0.5411		
0 3886	0.3667	
59°.90		
–	179°.095	
146°.57	114°.903	The increasing differences of temperature in this line may doubtless be referred chiefly to the gradual accumulation of soot.
7.078	7.4993	
8 1019	8 5842	
415.13	433.733	
9.1361	9 6113	The inferiority of the 3d to the 1st result may probably be accounted for, in part, by the heavy coating of soot accumulated on the absorbing surfaces of the boiler, and the consequent higher temperature at which the gases arrived at the chimney, and in part by the ash pit doors being kept open.
1.4171	1.4213	
6 1593	6.232	
Open.		
U. 8		

Remarks on the preceding experiments and deductions.

By admitting the air which supplied the combustion to come at once to the grate, at an average temperature of 73°.2, on the third trial, instead of going round the furnace, gathering the waste heat from the stack, and arriving at the grate in the rear of the closed ash pit with a temperature of 230°.2, as in the first experiment, the following effects appear to have resulted: *First*, The rate of *combustion* was increased from 122.8 to 127.6 pounds per hour. *Second*, The rate of *evaporation* was diminished from 15.93 to 13.71 cubic feet of water per hour. *Third*, The gases arrived at the chimney, after a circuit of 121 feet in horizontal flues, at a temperature of 379°, instead of 319°, as on the first-day of trial. *Fourth*, The evaporative effect of the coal, as seen in the 41st line, was reduced from 8.892 to 8.102; and that of the *combustible matter* alone, as found in the 43d line, from 9.916 to 9.136.

The comparison is made between the *first* and third trials, instead of the *mean of the first and second*, and the third; because the first and third were both conducted with the air plate at the furnace bridge *open*, whereas the second experiment was made with that plate *closed*.

Admitting that the air which passed through the furnace on the first and third days of trial was equally well employed, and equally deoxygenated, a computation founded on the analyses of the gases on the third trial, (table CXV,) may readily be made, which will show what was lost in burning with cold air instead of hot. Those analyses proved that, on an average, the weight of air equivalent in specific heat to the dry gases passing to the chimney during the combustion of a pound of *coal*, was 18.452 pounds. The waste matter from the furnace on that day was 11.32 per cent. Hence the weight of air equivalent to the gases from a pound of *combustible matter* is 20.81 pounds; and as the specific heat of air is 0.267 that of water, the equivalent weight of the latter material is 5.555 pounds. The heat imparted to the air and products of combustion on the third trial was 379°—73°.2=305°.8, which, multiplied by 5.555, gives 1698.9 as the *heating power*, or 1.649 as the *evaporative power* of this quantity of heat.

On the first day's trial, the air entered the grate at 230°, and the gases left the boiler at 319°, carrying away an excess of 89°. The total waste that day was 10.33 per cent., as seen in line 13 of the table. Hence the equivalent in air to the gaseous products from a pound of *combustible matter*, is 18.452÷0.8967=20.58; of which the heat absorbing power is by a similar computation 489, and the evaporative power equivalent to this is 0.475. The difference 1.649—0.489=1.160, added to the number 9.136 found in the 43d line of the table of deductions, gives 10.296; showing that the inferiority of the third to the first result (9.916) is rather more than compensated for by the cause now under consideration. Such, in fact, ought to be the case; since the fire doors were not kept open on the third trial quite to the end of the experiment, being closed at 4*h*. 30*m*. p. m. They were also closed for 43 minutes during one of the experiments in drawing gases from the chimney.

The 36th line of deductions shows that the average height of the draught gauge was 0.373 inch on the first trial, and 0.389 on the third. This is fully accounted for by the superiority in temperature of the gases on the third trial over those on the first, for 379°—319°=60°.

No. 4.

Bituminous coal sent for trial by the Creek Coal Company, Chesterfield county, Virginia.

The following letter accompanied this sample:

"RICHMOND, *June* 27, 1842.

"SIR: In compliance with the invitation of the Secretary of the Navy, I have sent by the schooner Pioneer five hogsheads containing two tons Creek coal, for experiment at your yard, with a view to test its fitness for generating steam on board the Government steamers.

"As there are other coals on board the vessel, you will oblige me by directing it to be kept separate.

"This coal is raised by the Creek Company, in Chesterfield county, on the south side of James river, 12 miles from tide water, with which the mines are connected by a railroad. The mines may be considered accessible at all seasons of the year, as it is a rare occurrence in our climate that navigation is closed by ice.

"Very respectfully, your most obedient servant,

"JOHN I. WERTH,
"*General Agent Creek Company.*

"Commodore BEV. KENNON."

The exterior characters of this coal are generally as follows: The surfaces of deposition are not continuously developed in the fractures. In place of them, a great number of conchoidal surfaces having a resinous lustre alternate with spaces of a dull aspect. The main partings are at right angles to the horizontal surfaces. The cross partings appear not to be well defined either in position or extent. The main partings are in some specimens very conspicuously marked with patches of sulphuret of iron. The specific gravity of one specimen was 1.3163; that of another, 1.3228; giving the calculated weight of one cubic foot of coal in the mine, 82.48 pounds. The average actual weight in the condition of lumps, (in which state it was mainly found when ready for use,) was, by 41 trials, 46.496 pounds, or 0.5636 of the calculated weight in the solid state. The highest result was 51.62, and the lowest 40.62 pounds per cubic foot. In the merchantable state, fit for use in the steamers, one ton will require for stowage 48.176 cubic feet of space.

On analyzing the two specimens above mentioned, they were found to contain the following materials:

	Specimen *a*.	Specimen *b*.
Moisture - - - -	1.074	1.112
Sulphur - - - -	(not tried)	2.894
Other volatile matter - - -	28.666	28.814
Ashes - - - - -	3.830	6.828
Fixed carbon - - - -	66.43	60.352
	100.	100.
Volatile to fixed combustible as	1 : 2.317	1 : 1.903

The coking of *a* was effected very slowly; that of *b* very rapidly. This, according to the result of a great number of trials, is sufficient to account for the difference in the relations of *volatile* to *fixed combustible* matter. On suddenly exposing a portion of this coal in powder to a bright red heat, the exterior becomes swollen and agglutinated, and at length hardened, before the interior has parted with all its gaseous matter. By continuing the heat, a quantity of confined gas is accumulated, sufficient to explode the agglutinated shell of the mass, which then develops a brilliant jet of flame.

The ashes from the analyses of specimen *a* are of a bright red; those of *b*, of a dull brick-red color.

The weight of coal burned during four trials of evaporative power was 3,769.63 pounds, from which were obtained as residua 157.29 pounds of ashes, weighing 56 pounds per cubic foot; and of clinker 167.68 pounds, weighing 39.5 pounds per cubic foot; also, 20.75 pounds of soot from the flues, weighing 14.33 pounds per cubic foot.

The combustible matter in the	*ashes*	was 9.84	per cent. of	their weight.
" "	*clinker,*	0.00	"	"
" "	*soot,*	34.27	"	"

The total quantity of matter absolutely incombustible is, therefore, 323.12 pounds, or 8.5717 per cent.

Twenty-eight pounds of this coal, dried for three days in the steaming apparatus, lost 0.406 pound, or 1.45 per cent.

Four trials of total volatile matter in two specimens of this coal afforded to Dr. King an average of 31.037 per cent. This result, combined with the two already given, presents an average of 31.118. From all these data, we may take the proximate constitution of this sample to be as follows, viz:

Moisture (from 28 pounds) - - - - -	1.450
Other volatile matter (mean of four specimens) -	29.678
Earthy matter (from 3,769.63 pounds) - -	8.572
Fixed carbon (calculated by difference) - -	60.300
	100.

Hence the volatile is to the fixed combustible 1 : 2.0318

It appears that both the specimens above analyzed gave proportions of earthy matter considerably below the practical average. The earthy matter of the clinker gained, instead of losing, by recalcination, to the amount of 1⅓ per cent., and became of a dark reddish brown. The ashes were, after reincineration, a lighter red than the clinker, and the residue of the soot still lighter than that of the ashes.

A trial by the oxide of lead on specimen *b*, gave a reduction of metallic lead equal to 28.1 times the weight of raw coal employed; and as the moisture and ashes of that specimen were together equal to 7.94 per cent., the lead to 1 of *combustible* was 30.523.

In ordinary smith's work, this coal was found to make a good hollow fire, with much flame; the heat from the latter very strong, but, of course, unavailable for the purposes of the work. In burning 60 pounds of it, the heating power developed was sufficient to put in nine links of a chain 1⅝ inch in diameter. In an office grate the ignition was easy; the flame copious; many jets of gas of a high illuminating power were from time

to time thrown out, giving a brisk noisy fire from the hissing of these jets. To those who admire a bright blazing fire, it will be found eligible for parlor and other domestic grates.

The mean time for bringing the boiler into full action was 1.166 hour, and the average quantity of unburnt coke left on the grate was 10.53 pounds.

The coke is considerably intumescent, and coheres firmly; and these circumstances prove that, before employing it in a blast furnace for smelting iron, the process of coking will be requisite. This process should be performed slowly, and ought not, when conducted on open hearths, to be pushed to the extent of expelling the last portions of volatile matter, lest a part of the fixed carbon be also consumed.

This coal is judged to be well adapted to the production of illuminating gas, with the exception of possessing, in some portions at least, too large a quantity of sulphur.

By a prompt application of heat, and a rapid development of the volatile constituents of the coal, a considerable portion of bi-carburetted hydrogen would be obtained, which is one of the principal objects of the gas manufacturer.

TABLE CXVII.—CREEK

First trial—upper damper 10

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 12	4.20	56	53	98	88	78	102	-	30.17	-	-	0.05	-	-
	6.35	61	56	94	96	78	98	-	30.19	-	-	0.22	-	-
	9.25	68	60	124	251	77	209	-	30.22	-	-	0.23	-	92.75
	9.50	72	61	133	270	77	227	-	30.22	0.223	8.34	0.23	-	92.25
	10.35	74	61	155	298	76	233	-	30.21	0.253	8.04	0.56	533	94.75
	11.15	75	61	178	334	77	233	-	30.21	0.242	8.15	0.40	1380	91.00
	11.30	74	60	192	322	77	235	-	30.21	0.257	8.00	0.63	1925	-
	P. M. 0.00	77	63	220	340	77	232	-	30.20	0.220	8.38	0.32	2685	94.50
	0.30	77	63	238	310	76	232	-	30.21	0.218	8.40	0.36	3370	91.75
	1.00	77	62	256	375	77	232	-	30.20	0.218	8.40	0.36	3805	99.00
	2.00	79	64	274	332	77	232	-	30.19	0.209	8.49	0.30	4950	100.75
	2.45	79	63	290	362	77	232	-	30.17	0.207	8.50	0.30	5445	89.50
	3.45	80	64	296	342	80	230	-	30.16	0.200	8.58	0.24	6690	92.25
	4.00	80	66	294	340	80	230	-	30.16	0.183	8.76	0.25	7093	-
	4.40	-	-	-	-	80	228	-	-	-	-	-	7290	
	A. M.													
June 13	5.00	67	63	176	184	76	210	-	29.99	-	-	0.16	7290	-
	5.25	68	62	174	-	76	206	-	-	-	-	0.16	7706	-

Period of steady action, from 10*h*. 35*m*. a. m. to 3*h*. 20*m*. p. m. = 4*h*. 45*m* ; coal supplied to grate, 658.25 lbs.; water to boiler, 5,636 lbs.; water to 1 of coal, 8.562.

COMPANY'S COAL.

inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	49.8	42	—14	-	Kindled fire in small furnace.
-	51.5	33	—2	-	Commenced firing under the boiler.
9.50	54.3	56	+45	-	Water in boiler brought to normal level; valves double weighted.
10.25	53.7	61	43	-	Wood consumed, 519 lbs.; commenced charging with coal; damper reduced to 10 inches, and double weights taken
10.35	52.5	81	65	1.889	off, at 10*h.* 5*m.* a. m.; air plates opened at 10*h.* 10*m.* a. m.; wind SE.; slightly hazy; sun shining.
11.15	52.0	103	101	3.358	Smoke 15½ seconds in reaching chimney top; syphon 0.40; wood ashes weighed 1.25 lb.
-	50.4	118	87	5.775	Drew 60 cubic inches gases from chimney while smoking, at 11*h.* 27*m.* a. m., which gave water 0.42 grain, car-
11.45	54.8	143	108	4.017	bonic acid 2.88 grains; steam allowed to escape from both valves, to obviate priming; sky overcast.
0.25	54.8	161	78	3.629	Drew 60 cubic inches gases from chimney, at 0*h.* 16*m.* p.m.;
1.00	52.8	179	143	2.305	which gave water 0.58 grain, carbonic acid 2.90 grains.
2.00	55.7	195	100	3.038	Placed 28 lbs. of the coal in the drying apparatus.
2.30	53.7	211	130	1.748	Filled tank; wind SE.; cloudy, with occasional sunshine.
3.20	60.7	216	112	3.298	Air plates closed; contents of ash pit thrown on grate; damper set at 5 inches.
-	58.9	214	110	4.270	Drew 60 cubic inches of gases at 1*h.* 30*m.* p. m.; which gave water 0.61 grain, carbonic acid 1.87 grain, oxygen 8.634 cubic inches; water at 0.4 inch above normal level.
-	60.5	109	—26		
-	58.1	106	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	37.00
Ashes	36.00
Ashes behind bridge	2.77
Total clinker and ashes	75.77
Deduct wood ashes, 1.59 lb., 1.25¼ of which had been previously removed	0.34
Total waste from coal	75.43
Coke	10.92

TABLE CXVIII.—CREEK

Second trial—upper damper 5

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
June 13	5 30	68	62	174	186	76	206	-	29.98	-	-	0.16	-	-
	7.00	71	64	154	240	76	225	-	29.97	0.155	9.04	0.20	-	90.75
	7.30	70	64	160	250	76	230	-	29.98	0.208	8.50	0.21	154	-
	8.00	70	65	162	275	76	230	-	29.96	0.220	8.38	0.28	489	95.00
	9.00	72	66	206	286	74	229	-	29.96	0.208	8.50	0.23	1067	97.75
	9.30	73	66	224	288	74	230	-	29.96	0.228	8.30	0.36	1469	90.25
	10.00	74	66	236	328	74	232	-	29.94	0.212	8.46	0.31	1965	97.50
	10.40	74.5	67.5	258	330	74	230	-	29.94	0.214	8.43	0.34	2704	99.00
	11.10	76	68	276	356	74	230	-	29.93	0.208	8.50	0.29	3217	-
	11.30	77	68	286	344	74	231	-	29.92	0.210	8.48	0.36	3472	98.75
	P. M.													
	0.10	81	69	306	-	74	230	-	29.90	0.212	8.46	-	4123	86.00
	0.45	81	70	310	340	74	230	-	29.90	0.208	8.50	0.33	4623	-
	1.35	84	71	320	358	78	230	-	29.88	0.200	8.58	0.30	5207	92.75
	2.00	86	72	332	338	78	230	-	29.85	0.203	8.54	0.32	5699	-
	2.30	86	72.5	336	360	78	230	-	29.86	0.193	8.66	0.30	6129	94.00
	3.55	-	-	-	-	80	-	-	-	-	-	-	6812	-
	A. M.													
June 14	5.10	-	-	-	-	80	214	-	29.72	-	-	-	6816	
	5.35	73	68	190	181	80	210	-	29.72	-	-	0.15	7262	-

Period of steady action, from 9*h.* 34*m.* a. m. to 2*h.* 25*m.* p. m. = 4*h.* 51*m.*; coal to grate for that period, 568 pounds; water to boiler, 4,522 pounds; hence, water to one of coal for this time, 7.961.

COMPANY'S COAL.

inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet; long steam pipe in chimney removed.
h. m.					
-	58.1	106	—20	-	Commenced firing.
7.00	59.9	83	+15	-	Wood consumed, 115 pounds; commenced charging with coal.
-	60.5	90	20	0.816	Steam blows off at 7*h*. 15*m*., at which time air plates are opened.
8.00	62.2	92	45	1.775	Filled tank at 8*h*. 15*m*.
8.35	62.8	134	57	1.531	Cloudy; wind SW.; smoke 22 seconds in reaching chimney top.
9.34	62.3	151	58	2.129	Drew at 9*h*. 55*m*. 60 cubic inches of gases, which gave water 0.68 grain, carbonic acid 4.17 grains, oxygen 8.664 cubic inches; smoke flowing from chimney whilst drawing gases.
10.00	61.8	162	96	2.628	
10.40	64.0	183.5	100	2.936	
-	64.2	200	126	2.719	
11.45	63.7	209	113	2.026	Commenced drawing gases at 0*h*. 8*m*.; drew in 6 minutes 60 cubic inches, which gave 0.59 grain water, 2.78 grains carbonic acid, and 8.634 cubic inches oxygen; no smoke from chimney during this drawing of gas; partly filled tank at 1*h*. 30*m*. p. m.
0.15	63.7	225	-	2.583	
-	65.3	229	110	2.271	
1.15	64.5	236	128	1.859	
-	66.6	246	108	3.128	
2.25	66.6	250	130	2.278	Air plates closed, and contents of ash pit thrown on grate.
-	-	-	-	-	Tank partly filled at 3*h*. 30*m*.; water in boiler left at 0.55 inch above normal level.
-	65.5	117	—29	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	45.75
Ashes	36.00
Ashes behind bridge	2.81
	84.56
Deduct wood ashes	0.353
Total waste from coal	84.207
Coke	5.69

TABLE CXIX.—CREEK

Third trial—upper damper 5 inches open; air

	h. m.			ATURES OF THE										
					Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	A. M.													
June 14	5.40	73	68	190	181	80	209	-	29.72	-	-	0.15	-	-
	6.40	74	69	186	302	80	227	-	29.73	0.177	8.82	0.22	-	61.25
	7.00	75	69	184	282	80	227	-	29.73	0.200	8.58	0.21	-	-
	7.20	75	71	187	274	80	230	-	29.73	0.226	8.41	0.21	172	94.00
	7.40	76	71	192	274	80	230	-	29.73	0.220	8.38	0.20	340	-
	[illegible]	77	71	202	276	80	229	-	29.73	0.204	8.54	0.21	605	98.25
	8.20	78	71	214	274	80	230	-	29.73	0.221	8.37	0.20	775	-
	8.40	[illegible]	73	236	282	80	230	-	29.73	0.218	8.40	0.20	946	-
	9.00	80	73	256	284	80	230	-	29.73	0.206	8.52	0.19	1113	97.75
	9.20	82	74	278	[illegible]	80	230	-	29.73	0.220	8.38	0.19	1287	-
	9.40	83	73	300	284	80	230	-	29.73	0.201	8.58	0.20	1450	-
	10.00	83	72	[illegible]	278	80	230	-	29.73	0.204	8.54	0.19	1610	-
	10.20	85	73	322	315	80	231	-	29.73	0.216	8.42	0.22	1780	[illegible]
	10.40	85.5	73.5	328	314	80	230	-	29.73	0.222	8.36	0.20	1948	-
	11.00	86	74	342	304	[illegible]	230	-	29.73	0.214	8.44	0.19	[illegible]	87.75
	11.20	86	76	340	290	[illegible]	232	-	29.73	0.234	8.24	0.24	2198	-
	11.40	86	76	348	308	78	232	-	29.73	0.222	8.36	0.22	2198	88.75
	P. M.													
	0.00	86	77	350	[illegible]	78	229	-	29.73	0.208	8.50	0.24	2980	-
	0.20	87	75	362	320	[illegible]	230	-	29.73	0.212	[illegible]	0.24	3237	91.00
	0.40	88	76	374	304	[illegible]	231	-	29.73	0.228	8.30	0.24	3405	-
	1.00	89	77	380	310	78	231	-	29.72	0.226	8.32	0.24	3580	-
	1.20	93	78	384	350	78	231	-	29.72	0.200	8.58	[illegible]	3875	83.50
	1.40	89	74	[illegible]	328	78	232	-	29.72	0.225	8.33	0.25	4132	-
	2.00	92	77	390	334	[illegible]	232	-	29.72	0.210	8.48	0.22	4340	-
	2.20	91	74	359	334	79	231	-	29.71	0.228	8.30	0.28	4515	-
	2.40	89	75	370	324	78	232	-	29.71	0.199	8.60	[illegible]	4770	94.25
	3.00	90	72	-	300	80	232	-	29.71	0.208	8.50	0.28	5012	-
	3.30	91	72	-	-	80	-	-	29.71	0.181	8.78	-	5429	-
	4.45	89	71	-	-	80	-	-	-	-	-	-	5761	-
	A. M.													
June 15	5.00	66.5	61	246	198	79	220	-	[illegible]	0.108	9.51	0.18	5761	-
	[illegible]	68.5	[illegible]	-	-	79	218	-	29.92	-	-	-	6189	-

Period of steady action, from 8*h.* 15*m.* a. m. to 2*h.* 30*m.* p. m.=6*h.* 15*m.* Coal to grate, 645 lbs.; water to boiler, 3,910 lbs.; hence, water to 1 of coal supplied for that time, 6.062.

COMPANY'S COAL.

plates closed; steam thrown out at back valve.

Time each charge was on grate.	[illegible]	grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	66.5	117	—27	-	Commenced firing; clear; wind W., light.
6.40	[illegible]	112	+75	-	Wood consumed, 122½ lbs. commenced charging with coal; steam at equlibrium.
-	66.2	109	55	-	Steam blowing off at 6h. 50m.; back valve unloaded.
7.20	69.2	112	44	1.366	
-	[illegible]	116	44	1.335	
8.15	68.4	125	47	2.106	
-	[illegible]	136	44	1.351	Wind SW., light; clear.
-	70.3	156	52	1.359	
9.06	[illegible]	176	[illegible]	1.062	Coal in drying apparatus weighs 27 lbs. 12 oz.
-	71.0	196	[illegible]	1.382	
-	69.2	217	54	1.296	
-	67.7	[illegible]	48	1.271	
10.00	[illegible]	237	64	1.351	Wind W., brisk; clear.
-	69.1	242.5	64	1.335	Sprinkling of rain.
11.00	69.7	256	74	1.987	Commenced drawing gases from lower flue at 11h. a. m.; drew in 19 minutes 100 cubic inches, which gave water 0.93 grain, carbonic acid 5.73 grains.
-	72.7	254	68		
11.40	72.7	262	[illegible]	-	Filled tank, water in boiler having fallen 0.7 inch below normal level.
-	74.1	264	95	2.071	Ceased raining, wind WNW.
[illegible]	[illegible]	275	90	2.042	Wind NW.
-	72.1	286	73	1.335	
-	73.2	[illegible]	79	1.391	
1.20	73.6	291	119	2.344	Commenced drawing gases at 1h. 20m. p. m. from lower flue; drew 100 cubic inches in 10 minutes, which gave water 0.98 grain, carbonic acid 6.02 grains, oxygen 10.55 cubic inches. No smoke from chimney during the drawing.
-	68.8	297	96	2.042	
-	72.4	298	[illegible]	1.653	
-	[illegible]	[illegible]	[illegible]	1.391	Smoke 20 seconds in reaching chimney top.
2.30	70.8	281	92	2.026	Filled tank at 2h. 55m. p. m.
-	65.2	-	68	1.282	Contents of ash pit on grate.
-	[illegible]	-	-	-	Water in boiler left at 0.7 inch above normal level.
-	63.4	-	-	-	Wind NW., light.
-	58.9	179.5	—22	-	Water 0.7 inch below normal level.
-	56.0	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	35.93
Ashes	40.50
Ashes, &c., behind bridge	2.70
Total clinker and ashes	79.13

	Pounds.
Deduct wood ashes	0.376
Total waste from coal	78.754
Coke	16.535

TABLE CXX.—CREEK

Fourth trial—upper damper 10 inches open;

Period of steady action this day, from 8*h*. a. m. to 1*h*. 15*m*. p. m.=5*h*. 15*m*.; coal supplied to grate during same time, 364.75 lbs.; water to boiler, 6,040 lbs.; water to 1 of coal, 7.959.

COMPANY'S COAL.

air plates closed; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	55.9	173.5	—26	-	Commenced firing; water in boiler 0.2 inch above normal level.
6.15	60.6	159	+94.5	-	Wood consumed, 87¾ lbs.; commenced charging with coal.
6.50	60.6	159	120	-	Steam blows off under the second weight, which was removed soon after.
-	61.6	145.5	170	2.694	
7.30	56.7	163	138	1.931	The third charge of coal is nearly all fine; the other charges this day used are mostly in lumps; the last charge had one large lump surrounded with fine coal.
8.00	59.8	182	168	1.287	
-	55.7	201	174	2.646	
8.30	55.7	211	211	1.128	
-	57.1	214	209	3.242	
9.05	58.9	226	192	4.212	
-	57.3	232.5	235	-	Filling tank; water in boiler, 0.9 inch below normal level; tank filled at 9*h.* 45*m.*; smoke 15.5 seconds in reaching chimney top; syphon, 0.31; extra weight removed from back valve; commenced drawing gases at 10*h.* 0*m.*; drew in 17 minutes 60 cubic inches, which gave water 0.45 grain, carbonic acid 3.31 grains; wind SW.; clear.
9.50	59.4	245	154	2.769	
10.20	56.2	300	148	2.405	
10.55	58.5	257	180	2.702	
-	56.2	268	135	2.352	
11.45	58.5	275	165	2.617	Commenced drawing gases second time at 11*h.* 33*m.*; drew in 9 minutes 60 cubic inches, which gave water 0.59 grain, carbonic acid 2.55 grains; no smoke from chimney.
-	62.0	281	159	1.955	
-	62.0	285	149	2.416	Coal in drying apparatus weighs 27 lbs. 9½ oz.
1.15	62.6	284	130	2.188	Smoke 24.5 seconds in reaching chimney top.
-	-	-	112	1.583	Contents of ash pit thrown on grate at 2*h.* 0*m.*
-	57.7	293	104	-	Filled tank; damper reduced to 3 inches.
-	59.5	293	2	-	Water in boiler left at 0.8 inch below normal level.
-	59.5	127	-	-	Water 0.3 inch below normal level.
-	61.3	119	—30	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	49.00
Ashes	35.75
Ashes behind bridge	2.97
Total ashes and clinker	87.72
Deduct wood ashes	0.269
Total waste from coal	87.451
Coke	8.98
Soot	20.75

TABLE CXXI.—DEDUCTIONS FROM

Experiments on Creek

	Nature of the data furnished by the respective tables.	1st Trial. (*T. CXVII.*)	2d Trial. (*T. CXVIII.*)
		June 12.	*June* 13.
1	Total duration of the experiment, in hours	25.083	24.083
2	Duration of steady action, in hours	4.75	4.85
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	10.0	10.0
7	Total weight of coal supplied to grate, in pounds	938.00	950.75
8	Pounds of coal actually consumed	927.08	945.06
9	Pounds of coal withdrawn and separated after trial	10.92	5.69
10	Mean weight, in pounds, of one cubic foot of coal	46.90	47.537
11	Pounds of coal supplied per hour, during steady action	138.56	117.11
12	Pounds of coal per square foot of grate surface, per hour	9.848	8.323
13	Total waste, ashes and clinker, from 100 pounds of coal	8.1363	8.910
14	Pounds of clinker alone, from 100 pounds of coal	3.9727	4.8209
15	Ratio of clinker to the total waste, per cent.	48.827	54.105
16	Total pounds of water supplied to the boiler	7706.0	7262.0
17	Mean temperature of water, in degrees Fahrenheit	77°.8	75°.5
18	Pounds of water supplied at the end of experiment, to restore level	416.0	446.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	55.0	57.0
20	Pounds of water evaporated per hour, during steady action	1186.52	932.3
21	Cubic feet of water per hour, during steady action	18.98	14.916
22	Pounds of water per square foot of heated surface per hour, by one calculation	3.143	2.469
23	Pounds of water per square foot, by a mean of several observations	3.409	2.456
24	Water evaporated by 1 of coal, from initial temperature (a) final result	8.252	7.624
25	Water evaporated by 1 of coal, from initial temperature (b) during steady action	8.562	7.961
26	Pounds of fuel evaporating one cubic foot of water	7.574	8.1978
27	Mean temperature of air entering below ash pit, during steady pressure	76°.50	76°.54
28	Mean temperature of wet bulb thermom., during steady pressure	62°.125	67°.71
29	Mean temperature of air, on arriving at the grate	225°.375	256°.33
30	Mean temperature of gases, when arriving at the chimney	334°.125	317°.55
31	Mean temperature of steam in the boiler	232°.625	230°.17
32	Mean temperature of attached thermometer	74°.00	74°.0
33	Mean height of barometer, in inches	30.200	29.927
34	Mean number of volumes of air in manometer	8.295	8.469
35	Mean height of mercury in manometer, in atmospheres	0.2280	0.2109
36	Mean height of water in syphon draught gauge, in inches	0.3814	0.3233
37	Mean temperature of dew point, by calculation	53°.34	63°.47
38	Mean gain of temperature by the air, before reaching grate	148°.875	179°.77
39	Mean difference between steam and escaping gases	101°.50	107°.33
40	Water to 1 of coal, corrected for temperature of water in cistern and boiler	8.2082	7.645
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern and boiler	9.2761	8.6582
42	Pounds of water, from 212°, to 1 cubic foot of coal	435.05	411.58
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.0977	9.5051
44	Mean pressure, in atmospheres, above a vacuum	1.449	1.4069
45	Mean pressure, in pounds per square inch, above atmosphere	6 6312	6.0094
46	Condition of the air plates at the furnace bridge	Open.	Open.
47	Inches opening of damper, (U. upper)	U. 10	U. 5

TABLES CXVII, CXVIII, CXIX, CXX,

Company's coal.

3d Trial. (*Tab. CXIX.*)	4th Trial. (*Tab. CXX.*)	Averages.	Remarks.
June 14.	*June* 15.		
23.917	24.25		
6.25	5.25		
14.07	14.07		
377.5	377.5		
18.75	18.75		
10.0	11.0		
918.5	1005.5		
901.97	996.52		
16.53	8.98	10.53	When, on the 3d trial, the combustion was conducted with the damper drawn but 5 inches, the weight of coke left unburnt was 16.53 lbs.; and on the 4th trial, with damper 10 inches, the unburnt coke was 8.98 lbs.
45.925	45.705	46.517	
106.033	122.04	120.936	
7.536	8.673	8.595	
8.731	8.785	8.6406	
3.9658	4.9011	4.4151	
45.42	51.018	49.8425	
6188.0	7089.0		
79°.1	77°.5		
427.0	240.0		
55.0	31.0		
642.775	960.0	930.399	
10.284	15.36	14.885	From the great activity of the fire in the early part of the first experiment, the water occasionally rose in foam, and discharged a little spray, until the back valve was unloaded; the evaporation is, therefore, suspected to be given too high.
1.703	2.543	2.4645	
1.568	2.439		
6.799	7.089	7.441	
6.062	7.959	7.636	
9.1925	8.8165	8.4452	
84°.43	81°.47		
74°.07	66°.24		
311°.09	313°.18	276°.494	
301°.09	398°.82	337°.896	The temperature of the gases on arriving at the chimney was generally higher when the coal was burned with the open air plate than when with it closed; but in the 4th trial, when the flues had become much coated with soot, the temperature of escaping gases was nearly 70° higher than during the first and second experiments.
230°.60	231°.94		
81°.00	78°.0		
29.727	29.961		
8.419	8.436		
0.2166	0.2144		
0.22	0.3469	0.3179	
70°.40	58°.75		
226°.66	231°.75	196°.764	
75°.73	172°.00	114°.14	
6.8605	7.0649	7.4446	
7.7457	7.9874	8.4168	
355.72	365.07	391.855	
8.4867	8.7567	9.2115	In these trials, it appears that the open air plate at the furnace bridge, together with the freedom of the flues from soot in the first two trials, produced results decidedly superior to those obtained in the opposite circumstances at the 3d trial.
1.445	1.4237	1.4311	
6.5717	6.2579	6.3675	
Closed.	Closed.		
U. 5	U. 10		

General remarks on the preceding table of deductions, and on the experiments from which it is derived.

In all the experiments on the coal of the Creek Company, it will be observed that the grate remained of the same size, the circuit for the gases of the same length, and the chimney of the same height. The weight of coal burned at each experiment was also nearly the same. The period of steady action varied from 4.75 to 6.25 hours.

The rate of combustion appears to have been considerably more rapid on the first than on any of the subsequent trials, being 9.848 pounds per square foot of grate surface per hour, while the average for the other three days was but 8.177 pounds. The proportion of the *total waste* on the several days of trial varied but little. It was least when the rate of combustion was greatest—that is, on the first trial. This uniformity in the earthy residue shows that the sample had been so prepared for use as to exhibit a nearly equal purity throughout; very different from what happened in several other samples sent for these experiments.

It appears from the 18th line of the table of deductions, that, with the exception of the last trial, nearly the same quantity of water was supplied on each morning after terminating an experiment, in order to restore the level of water in the boiler to correspond to the existing temperature.

The rate of evaporation was very different on the different trials: 18.98 cubic feet of water were evaporated per hour on the first, and only 10.28 on the third. The average rate for four days was 14.885, which is between the free-burning bituminous coals and the artificial cokes already exhibited in connexion with the synoptical table of the free-burning class. The evaporative efficiency of the pound of coal given on the first trial (line 41) is materially above that in either of the others, and leads to the suspicion that the brisk action of the fire may have caused some water to escape on that day mechanically mixed with the steam. It was on that occasion found necessary to allow the steam to escape at both valves, in order to equalize the pressure, and prevent too much local ebullition by the current of steam flowing towards a single point of exit.

The two trials with the air plate open have evidently given results (as seen in line 43) which considerably surpass those obtained with the plate closed. This appears, in fact, to be the principal circumstance which caused a marked difference in the effect of this coal on the separate days of trial.

The tables of experiments show that the products of combustion were analyzed either wholly or partially on every day during the combustion of this sample. On the first day were made three; on the second, third, and fourth, each, two analyses. One point attempted to be ascertained by these trials, was the relative proportion of the principal products when, in the one case, smoke was flowing copiously from the chimney, and, in the other, when it discharged only invisible gases. It appeared, as a general result, that carbonic acid was in greatest abundance while smoke came most copiously from the flue, and that aqueous vapor was not then relative in so great quantity as at a subsequent period, when the smoke had disappeared.

No. 5.

Bituminous coal from the Clover Hill mines, on the Appomattox river, Virginia.

The following letter states the origin of this sample, and gives other requisite information:

"PETERSBURG, *June* 13, 1842.

"DEAR SIR: In consequence of the desire expressed by the Board of Navy Commissioners to be furnished with specimens of the different *American coals*, I have taken the liberty to order to be sent to the navy yard at Washington five hogsheads, containing a little upwards of two tons of coal, from the Clover Hill mines. This I hope the Board will do me the favor to receive, and submit to such tests and analyses as, in their opinion, may be calculated to prove its adaptation to steam purposes.

"The Clover Hill mines are situated on the Appomattox river, about twenty miles above the town of Petersburg, State of Virginia. The present shipping point for the coal is Petersburg, or City Point; and it can be delivered more cheaply or expeditiously at *Norfolk* than any other town or city on the Atlantic seaboard; but it may be shipped to any other seaport town, though at greater cost, as the location of its shipping point shows.

"As may be seen by examination of the specimen sent, from the square fracture and hard grain of this coal, it may be raised and transported in a lumpy state. The specimen sent was extracted from the mine about the 15th day of May last, and from that time till within a few days has been exposed to the sun and weather.

"The specimen was taken from a cargo recently shipped to the navy yard at Gosport, in fulfilment of a contract made by the Clover Hill Company to furnish 800 tons of coal at that point for the use of the Government. I would respectfully suggest to the Board the propriety of seeking from the commandant of the Gosport station information in relation to the quality and size of the Clover Hill coal delivered there, as compared with coal delivered there by other contractors. It must be more satisfactory to be informed of the character and quality of coal, as well in mass as in specimens; for all mines will produce specimens superior to the general richness of the vein.

"If the Board be pleased with the coal, and desire a supply beyond the present contract, the Clover Hill Company are prepared to extend the contract to 2,000 or 3,000 tons, to be shipped during the summer or the next winter, for the same price per ton as the contract already made.

"I have not thought fit to trouble the Board with a particular description of the Clover Hill mines, or to enter into details in regard to the thickness and extent of the vein, the facilities of transportation, &c., because not informed that such information was desired. But this, or any other information I have on the subject of coal in this section of the country, will be cheerfully furnished them at any time they may indicate a wish to receive it. I am pleased to see that the Navy Board have determined to seek information in regard to the adaptation of different coals to uses of generating steam. It is a subject of growing interest and importance; and the plan adopted to get information by an actual test of the different varieties, is

probably the best for both the miner and the Government that could have been adopted.

"Very respectfully, your obedient servant,

"JAMES H. COX,
"*President of Clover Hill Company.*"

This coal differs considerably in aspect from any of the Virginia coals hitherto described. The color is dull black, and the surface is not unfrequently coated with carbonate of lime in scales of considerable thickness. The main partings are inclined in an angle of about 85° to the surfaces of
stre is mostly glimmering or resinous. The scales of
e marked with specks of oxide of iron. The lumps,
eighteen months, tend to disintegrate. The surfaces
t, in some cases, the conchoidal fractures already no-
other samples from the same coal field.
ity of one specimen (*a*) of this coal was found to be 1.2823, and that of another (*b*) 1.2887; from which the weight per cubic foot of the solid coal is calculated to be 80.355 pounds.

On weighing in the charge box, mostly in the state of lumps, all the coal burned at four trials, the result was 45.485 pounds per cubic foot; the highest number found in any one trial being 53.5, and the lowest 40.875. The average weight thus obtained is 0.566 of the calculated weight derived from the specific gravity.

The space for stowing 1 ton is 49.247 cubic feet.

The moisture expelled in analyzing specimen *a* was 1.409, and in *b* 1.277 per cent.

Twenty-eight pounds of the coal, in its average state, exposed for four days in the steam drying apparatus, lost 6 ounces, or 1.339 per cent.

Specimen *b* gave of sulphur 0.5139 per cent. The volatile matter, excepting moisture, in *a* was 31.791; and, excepting moisture and sulphur, in *b* it was 28.409.

Of ashes, 87.12 grains of *a* gave 5.46 grains, or 6.267 per cent.; 303.07 grains of *b* gave 13.26 grains, or 4.3752 per cent.

From these data, we have—

	Specimen *a*.	Specimen *b*.
Of moisture - - -	1.409	1.277
Of sulphur - - -	(not tried)	0.514
Of other volatile matter - -	31.791	28.409
Of earthy impurities - -	6.267	4.375
Of fixed carbon - - -	60.533	65.425
	100.	100.
The volatile to the fixed combustible	1 : 1.904	1 : 2.268

Two specimens, examined by Doctor King, gave, respectively, 31.25 and 37.50 per cent. of volatile matter, including moisture; and, as the two above given afforded the numbers 33.2 and 30.2 for the same ingredients, it may probably be safe to assume the mean of these four numbers, or 33,037, as the total volatile matter of this coal on a large scale, including hygrometric moisture. From this deducting 1.339, the moisture found in the steaming apparatus, we have 31.698 as the per centage of volatile combustible.

During four trials of evaporative power, there were burned 3,775.1 pounds of this sample; and the weight of *ashes* was 246.655 pounds, of *clinker* 149 pounds, and of *soot* 42 pounds. The ashes weighed 53.81 pounds per cubic foot, and lost by reincineration 14.93 per cent. The clinker weighed 44.62 pounds per cubic foot; lost nothing by calcination; but, on the contrary, gained very nearly 1 per cent. by peroxidizing the iron, which was previously partly in the state of magnetic oxide. The soot weighed 9.2 pounds per cubic foot, and lost 43.67 per cent. of its weight by incineration.

After making these deductions for combustible ingredients in the several residua, there were left 382.49 pounds of matter absolutely incombustible, or 10.132 per cent. From this analysis of the whole sample, we have—

Moisture - - - - - -	1.339
Volatile matter other than moisture - - -	31.698
Ashes - - - - - - - -	10.132
Fixed carbon - - - - - - -	56.831
	100.

This gives the relation of the volatile to the fixed combustible matter as 1 : 1.7929.

Oxide of lead reduced by specimen *b* gave 26.962 times its weight in metallic lead. Deducting ashes and moisture, this gives of lead to 1 of combustible matter 28.527.

On specimen *b* an experiment was made by the organic method of analysis.

For this purpose, 6.05 grains of the coal, perfectly dried, were treated with all the usual precautions with the scale oxide of copper. As the *raw* coal had 1.277 per cent. of moisture, and 4.3752 per cent. of ashes, the per centage of *dry* coal, which is composed of combustible ingredients, is 100—4.4318=95.5682; which shows that in 6.05 grains of dry coal there were 5.7818 grains of combustible materials.

The water collected in the chloride tube, and sulphuric acid bulb, weighed - - - - - -	2.58 grs.
The carbonic acid in the three tubes for its reception - -	17.68

Hence, the hydrogen is 0.2866, ($=\frac{1}{9}$ of the water,)
and the carbon 4.8217, ($=\frac{6}{22}$ of the carbonic acid.)

The sum of these = 5.1083, deducted from 5.7818, leaves for oxygen and azote 0.6735.

Hence, the composition of 100 parts of the *combustible matter* of the dry coal is—

Carbon - - - - - - -	83.393
Hydrogen - - - - - - -	4.958
Oxygen and azote - - - - - -	11.649
	100.

As the volatile matter, other than moisture, in 100 of the raw coal, was found, by previous experiment, to be 28.923 per cent., we may, from the foregoing analysis, deduce the weight of carbon which that volatile matter contained.

Thus, as the moisture is		1.277	per cent.
Ashes		4.375	"
Fixed and volatile combustible (94.348) composed of	Carbon	78.680	"
	Hydrogen	4.677	"
	Oxygen and azote	10.991	"

the sum of the last two, 15.668, subtracted from 28.923, leaves for carbon, in the volatile matter, 13.255.

Deducting the amount of hydrogen equivalent to saturate the oxygen in the coal, we have left 3.303 parts; and admitting the heating power of this to be 62,535, according to the result of Dulong's researches, we obtained $62535 \times 0.03303 = 2065.5 =$ the weight of water heated one degree Fahrenheit by the burning of the hydrogen in one pound of this coal. By assuming the heating power of carbon to be 12.906, according to the same authority, we have $12906 \times 78.68 = 10154.5 =$ the heating power from the carbon in one pound of coal. The sum of these two numbers is $12.220 =$ the number of pounds of water heated 1° by the combustible ingredients, omitting the sulphur. This number, divided by 1030°, the latent heat of the vapor of water, gives 11.864 pounds of water converted into steam from 212°, by the combustion of one pound of this coal.

Comparing the above result with the practical heating power, as given in the table of deductions, we have a wide difference. The highest amount of water from 212° to 1 of coal, was only 8.0468. The apparatus for drawing gas from the chimney had not been arranged at the time this sample was burned; and I cannot, therefore, offer any *direct* observations to test the products of its combustion, from which to derive its heating power, such as are contained in a subsequent part of the report, upon various other samples of coal.

But we may deduce this from another source.

The table of deductions, following those of experiments on this coal, furnishes the highest amount of water evaporated from 212° to 1 of *combustible matter* in the coal, 9.1513, and the average 8.5885.

In burning the *Tippecanoe* coal, (which is in all respects a perfect counterpart of the Clover Hill, the two pits being, I understand, in close proximity and on the same bed,) the gases of the chimney were analyzed, and the heat expended on all the principal absorbents is calculated. The evaporative power of 1 of coal in that case, as derived from the steam it expelled from the boiler, was 8.408; and the total power expended on all the absorbents is 10.29. Hence, of the total evaporating power measured, there was employed on the boiler 81.504 per cent.

The water evaporated by 1 of combustible matter on the same day was 9.2932; and the total evaporative power to 1 of combustible must, therefore, have been 11.402.

Taking 81.504 per cent. as the proportion of heat expended on the boiler in the case of Clover Hill coal, the total *maximum* evaporative power of 1 of combustible was $9.1513 \div 0.81504 = 11.228$; and the *average* is $8.5885 \div 0.81504 = 10.537$. To compare this with the result of the above analysis, we have the carbon in one of combustible 0.83393: and this multiplied by 12906, gives 10745 as the *heating* power; and the *steam evaporating power* is $10745 \div 1030 = 10.445$. Hence, the carbon alone appears to be adequate to produce the whole *average* evaporative effect observed. The excess of hydrogen was 0.03502 of the combustible matter, and $0.03502 \times$

62535÷2190= the computed heating power of the hydrogen, of which the equivalent in *evaporative power* is 2.126.

When tried in the smith shops, the workmen complained that this coal made a large amount of cinder; would not form a good hollow fire of any considerable durability; and that it corroded, or, as one expressed it, "ate up" the iron.

In burning, it falls into small lumps, which, under the steam boiler, occasioned a large portion to pass through the grate, and in the smith's fire prevented forming a durable arch. In office and parlor grates, the same cause produces a strong tendency to waste.

For the manufacture of iron, it will require coking and where this operation is performed on large quantities, the agglutination may probably be sufficient to constitute a suitable fuel for that purpose.

The average time required to bring the boiler to steady action, while burning this coal, was 1.933 hour.

The weight of coke left unburnt 11.512 pounds.

It will be remarked that it yields a very large amount of soot. The accumulation of it in the interior flues of the boiler was such as to diminish their opening nearly one-half; and in the outside flues, the surface of the boiler there exposed was covered from an inch to an inch and a half in thickness, in the course of four trials.

TABLE CXXII.—CLO

First trial—upper damper 12

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
May 2	5.00	54	-	100	138	63	154	-	30.20	-	-	0.08	-	-
	7.40	5..5	-	110	192	63	202	-	30.27	-	-	0.12	-	-
	8.20	54	-	130	222	63	225	-	30.28	0.177	8.82	0.10	-	-
	8.40	55	-	138	226	62	228	-	30.27	0.193	8.66	0.11	-	84.50
	9.00	58	-	154	231	62	229	-	30.27	0.193	8.66	0.12	230	-
	9.15	59	-	165	233	62	229	-	30.28	0.193	8.66	0.11	280	84.50
	9.45	60	-	196	247	61	229	-	30.28	0.197	8.62	0.12	615	75.50
	10.00	60	-	234	260	60	229	-	30.28	0.195	8.64	0.12	1020	-
	10.30	60	-	264	269	60	227	-	30.28	0.195	8.64	0.13	1275	86.75
	11.20	60.5	-	334	270	61	228	-	30.28	0.191	8.68	0.14	1865	96.25
	P. M.													
	0.05	60	-	368	272	61	228	-	30.27	0.193	8.66	0.14	2555	92.50
	1.00	61	-	402	267	61	228	-	30.26	0.189	8.70	0.15	3125	102.00
	1.30	62	-	424	251	62	228	-	30.24	0.185	8.73	0.13	3605	-
	2.00	62	-	434	270	62	228	-	30.24	0.186	8.72	0.13	3945	105.75
	2.30	63	-	440	252	62	228	-	30.24	0.185	8.73	0.13	4065	-
	3.00	64	-	450	257	67	228	-	30.23	0.184	8.74	0.13	4395	102.75
	3.40	64	-	460	256	68	228	-	30.23	0.177	8.82	0.15	4885	84.00
	4.20	64	-	470	252	68	228	-	30.23	0.180	8.79	0.13	5135	-
	4.50	65	-	474	244	68	228	-	30.22	0.177	8.82	0.12	5475	93.00
	5 26	65	-	480	241	68	228	-	30.22	0.179	8.80	0.13	5730	97.25
	6.15	65	-	490	230	68	228	-	30.22	0.171	8.88	0.13	6185	92.50
	6.30	65	-	488	240	68	226	-	30.22	0.159	9.00	0.12	6760	-
	.. M.													
May 3	5.00	56	-	260	194	67	214	-	30.31	-	-	0.12	6760	-
	5.50	55	-	244	188	65	202	-	30.32	-	-	0.14	8355	-

Period of steady action, from 9*h*. 45*m*. a. m. to 6*h*. 15*m*. p. m. = 8*h*. 30*m*. Coal supplied to the grate, 952.75 lbs.; water to the boiler, 5,570 lbs.; water to 1 of coal, 5.846. (More coal was doubtless on the grate at the end, than at the beginning of the assumed period of steady action.)

VER HILL COAL.

inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	50	—16	-	Fire kindled at 5*h*. 30*m*. a. m.
-	-	58 5	—10	-	Water in boiler at normal level.
-	-	76	— 3	-	Wood 342½ lbs.; steam begins to blow off; commenced charging with coal; filled tank at 8*h*. 30*m*. a. m.
8.40	-	83	— 2		
....	....	....			
-	-	96	+ 2	1.828	Placed 28 lbs. of coal in the drying apparatus.
9.15	-	106	4	0.529	Damper 14 inches open.
9.45	-	136	18	1.775	
....			....	....	
-	-	174	31	-	Smoke constant at chimney top, especially dense at charging.
10.30	-	204	42	2.331	The fluid in syphon too thick to flow properly.
11.20	-	273.5	42	2.344	By a mean of three observations, smoke 26 seconds in reaching chimney top.
0.05	-	308	44	2.437	
1.00	-	341	39	1.646	
-	-	362	23	2.543	
2.00	-	372	42	1.801	
-	-	377	24	0.635	Filled tank at 2*h*. 30*m*. p. m.
3.00	-	386	29	1.748	
3.40	-	396	28	1.947	
-	-	406	24	0.993	Gases take 31 seconds to reach chimney top.
4.25	-	409	16	1.801	
5.25	-	415	16	1.158	
6.15	-	425	2	1.446	
....	....	....	....	....	
-	-	423	14		
-	-	204	—20		
-	-	189	—14	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	56.50
Ashes	41.50
Ashes behind bridge	15.65
Total clinker and ashes	113.65
Deduct wood ashes	1.051
Total waste from coal	112.599
Coke	6.25

TABLE CXXIII.—

Second trial—upper damper 12

Date.	Hour.	Temperatures of the Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
May 3	6.50	55	-	244	188	65	202	-	30.32	-	-	0.14	-	-
	7.35	55	-	226	234	63	204	-	30.32	-	-	0.12	-	-
	8.45	55	-	236	274	61	226	-	30.31	0.159	9.00	0.12	-	-
	9.00	55.5	-	220	271	61	228	-	30.32	0.177	8.82	0.14	-	-
	9.20	55.5	-	232	280	61	227	-	30.32	0.182	8.76	0.14	-	85.75
	10.10	56	-	240	286	62	227	-	30.32	0.188	8.70	0.14	245	89.50
	10.40	56	-	254	280	62	228	-	30.32	0.182	8.76	0.14	465	-
	11.20	56.5	-	264	298	62	228	-	30.31	0.188	8.71	0.13	665	-
	P. M.													
	0.00	57	-	312	308	63	228	-	30.32	0.187	8.72	0.15	985	92.25
	0.30	57	-	336	310	61	227	-	30.31	0.187	8 72	0.15	1315	-
	1.00	58	-	370	308	62	228	-	30.31	0.190	8.69	0.14	1565	93.25
	1.40	59	-	386	310	62	228	-	30.30	0.180	8.79	0.15	2005	100.25
	2.30	60	-	410	304	62	228	-	30.28	0.187	8.72	0.15	2300	-
	2.50	60	-	415	306	62	228	-	30.28	0.187	8.72	0.16	2545	86.25
	3.40	60.5	-	-	306	62	228	-	30.28	0.185	8.74	0.16	2970	-
	4.20	61	-	-	306	63	228	-	30.28	0.177	8.82	0.15	3410	83 50
	5.00	61	-	-	300	63	228	-	30.28	0.184	8.74	0.15	3730	95.00
	5.40	61	-	350	294	63	228	-	30.28	0.181	8.78	0.17	3960	-
	6.10	60	-	435	294	63	228	-	30.28	0.182	8.76	0.14	4125	82.75
	A. M.													
May 4	6.30	-	-	-	-	-	-	-	-	-	-	-	4745	-
	5.30	52	-	-	194	63	206	-	30.32	-	-	0.10	5730	-

Period of steady action, from 11*h.* 40*m.* a. m. to 6*h.* 10*m.* p. m.=6*h.* 30*m.*; coal supplied to the grate, 541 lbs.; water to the boiler for the same time, 3,300 lbs.; water to 1 of coal, 6.099.

CLOVER HILL COAL.

inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	189	—14	-	Kindled fire.
-	-	171	+30	-	Filled tank.
-	-	181	48	-	Wood consumed, 171¼ lbs.; steam at equilibrium; commenced charging with coal.
-	-	164.5	43	-	Steam begins to blow off; upper damper 16 inches open.
9.20	-	176.5	53		
10.10	-	184	59	-	Damper set at 12 inches.
-	-	198	62	1.166	Damper at 6 inches.
-	-	107.5	70	0.795	
11.40	-	255	80	1.271	
-	-	279	83	1.748	
0.45	-	312	80	1.324	
1.43	-	327	82	1.748	
-	-	350	76	0.938	
2.50	-	355	78	1.947	Coal in drying apparatus weighs 27 lbs. 13 oz.
-	-	-	78	1.033	Smoke 25 seconds in reaching chimney top.
4.00	-	-	78	1.748	
5.00	-	-	72	1.314	Filled tank at 5*h.* 30*m.*
-	-	289	66	0.914	The lighter charges were entirely or chiefly lumps—the heavier, mostly fine coal.
6.10	-	375	66	0.874	Contents of ash pit thrown on grate.
-	-	-	-	-	Water in boiler found 2.1 inches below normal level at 212°.
-	-	-	—12	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	32.50
Ashes	53.75
Ashes behind bridge	10.61
	96.86
Deduct wood ashes	0.526
Total waste from coal	96.334
Coke	10.43

TABLE CXXIV.—CLO

Third trial—upper damper 6

Period of steady action, from 9*h*. 45*m*. a. m. to 6*h*. 10*m*. p. m. = 8*h*. 25*m*. Coal supplied to the grate, 627.75 lbs.; water to boiler, same time, 4,160 lbs.; hence, water to 1 of coal, 7.906.

VER HILL COAL.

inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.352 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet; holes in air plates 0.4 inch in diameter.
h. m.					
–	–	95	— 44	–	Commenced firing.
7.00	–	97	+ 42	–	Wood consumed, 127 lbs.; commenced charging with coal steam at equilibrium.
–	–	94	47	–	Upper damper set at 17 inches; steam blows off; opened (
	....	....			rows of holes in air plates; at 8*h*. 15*m*. a. m. damper re-
–	–	113.5	68	0.936	duced to 10 inches; smoke at chimney top whilst charg-
8.45	–	124	91	1.456	ing and stoking.
9.45	–	172	102	0.795	Damper reduced to 8 inches; air plates entirely opened at
....			....	....	10*h*. 5*m*. a. m.
–	–	204	105	1.430	Smoke 26 seconds in reaching chimney top.
11.00	–	221.5	112	1 322	Some smoke at chimney top.
–	–	238	117	1.689	Filled tank at 11*h*. 55*m*.
0.15	–	253	117	0.727	Smoke from chimney.
1.10	–	293	113	1.430	Damper reduced to 6 inches.
2.30	–	301	101	1.987	
–	–	320	97	1.148	
3.45	–	320	95	0.795	
–	–	328.5	95	1.775	Steam very low; smoke at chimney top.
–	–	340.5	92	1.180	
5.00	–	334.5	90	1.509	The lightest charges consisted almost entirely of lump coal.
–	–	346.5	91	1.490	Filled tank.
6.10	–	361	95	2.089	
....	....	....	....	....	
–	–	355	90	–	Contents of ash pit thrown on grate; water left 1.4 inch above normal level.
–	–	184.5	— 22		
–	–	179	— 28	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	30 00
Ashes	51.75
Ashes behind bridge	11.74
Total clinker and ashes	93.49
Deduct wood ashes	0.39
Total waste from coal	93.10
Coke	18.00

TABLE CXXV.—CLO

Fourth trial—upper damper 12

Period of steady action, from 9*h*. 45*m*. to 5*h*. 0*m*. p. m.=7*h*. 15*m*. Coal supplied to the grate in the same time, 611.5 lbs., water to the boiler, 3,120 lbs.; water to 1 of coal, 4.863.

VER HILL COAL.

inches open; air plates open.

				Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.352 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
-	-	179	—26	-	Commenced firing.
-	-	167	+39	-	Wood consumed, 123½ lbs.; commenced charging with coal; steam at equilibrium.
8.05	-	161	[illegible]	-	Steam begins to blow off; upper damper set at 12 inches.
8.45	-	166	121	1.363	Coal in drying apparatus weighs 27 lbs. 10 oz.
-	-	192	129	0.927	
9.45	-	217	[illegible]	[illegible]	
10.15	-	250	[illegible]	1.351	
-	-	297	[illegible]	0.900	Considerable smoke at chimney top.
11.15	-	[illegible]	128	1.573	
0.10	-	366	116	1.271	
-	-	379	109	1.232	
1.15	-	411	124	1.953	
-	-	394	121	-	Filled tank.
2.30	-	[illegible]	108	1.059	As in the preceding experiments, the lighter charges were chiefly lumps, the heavier mostly fine coal.
3.30	-	451	89	0.967	
-	-	[illegible]	89	0.874	Smoke flowing from chimney.
5.00	-	470	76	0.869	Contents of ash pit thrown on grate, and air plates closed.
-	-	470	75	1.256	Water in boiler left 1.4 inch above normal level.
-	-	[illegible]	— 8	-	Water 1.75 inch below normal level.
-	-	192	— 1	-	Water in boiler adjusted.

RESIDUA.

	Pounds
Clinker - - - - - - - - - - -	30.00
Ashes - - - - - - - - - - -	52.00
Ashes behind bridge - - - - - - - - -	12.00
Total clinker and ashes - - - - - - - -	94.00
Deduct wood ashes - - - - - - - - -	0.379
Total waste from coal - - - - - - - -	93.621
Coke - - - - - - - - - - - -	11.375
Soot - - - - - - - - - - - -	42.00

TABLE CXXVI.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (*Table CXXII.*)	2d Trial. (*Tab. CXXIII.*)
		May 2.	*May* 3.
1	Total duration of the experiment, in hours - -	25.0	23.33
2	Duration of steady action, in hours - - -	8.5	6.5
3	Area of grate, in square feet - - - - -	16.25	16.25
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	21.66	21.66
6	Number of charges of coal supplied to grate - -	13.0	9.0
7	Total weight of coal supplied to grate, in pounds -	1197.25	808.5
8	Pounds of coal actually consumed - - -	1191.0	798.07
9	Pounds of coal withdrawn and separated after trial -	6.25	10.43
10	Mean weight, in pounds, of one cubic foot of coal -	46.048	44.36
11	Pounds of coal supplied per hour, during steady action -	112 08	83.23
12	Pounds of coal per square foot of grate surface, per hour	6.897	5.121
13	Total waste, ashes and clinker, from 100 pounds of coal	9.4326	12.069
14	Pounds of clinker alone, from 100 pounds of coal -	4.7003	4.0423
15	Ratio of clinker to the total waste, per cent. - -	49.716	33.488
16	Total pounds of water supplied to the boiler - -	8355.0	5730.0
17	Mean temperature of water, in degrees Fahrenheit -	65°.0	62°.3
18	Pounds of water supplied at the end of experiment, to restore level - - - - - -	1595.0	985.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds - - - -	221.0	139.0
20	Pounds of water evaporated per hour, during steady action	655.29	507.7
21	Cubic feet of water per hour, during steady action -	10.48	8.12
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - -	1.735	1.345
23	Pounds of water per square foot, by a mean of several observations - - - - - - -	1.756	1.351
24	Water evaporated by 1 of coal, from initial temp. (a) final result - - - - - - -	6.8379	7.0056
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action - - - - -	5.846	6.099
26	Pounds of fuel evaporating one cubic foot of water -	9.1402	8.9213
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - -	61°.91	58°.79
28	Mean temp. of wet bulb thermom., during steady pressure	-	-
29	Mean temperature of air, on arriving at the grate -	367°.0	343°.0
30	Mean temperature of gases, when arriving at the chimney	241°.47	300°.71
31	Mean temperature of steam in the boiler - -	228°.18	227°.86
32	Mean temperature of attached thermometer - -	59°.0	56°.0
33	Mean height of barometer, in inches - - -	30.251	30.296
34	Mean number of volumes of air in manometer - -	8.723	8.741
35	Mean height of mercury in manometer - -	0.186	0.1845
36	Mean height of water in syphon draught gauge, in inches	0.1328	0.1518
37	Mean temperature of dew point, by calculation.		
38	Mean gain of temperature by the air, before reaching grate	295°.09	284°.21
39	Mean difference between steam and escaping gases -	13°.29	72°.85
40	Water to 1 of coal, corrected for temperature of water in cistern - - - - - - -	6.8278	7.0257
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - -	7.8023	8.0468
42	Pounds of water, from 212°, to 1 cubic foot of coal -	359.28	356.96
43	Water, from 212°, to 1 pound of combustible matter of the fuel - - - - - - -	8.6149	9.1513
44	Mean pressure, in atmospheres, above a vacuum -	1.4277	1.4164
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.3164	6.1494
46	Condition of the air plates at the furnace bridge -	Removed.	Removed.
47	Inches opening of damper, (U. upper) - -	U. 12	U. 12

TABLES CXXII, CXXIII, CXXIV, CXXV.

Clover Hill coal.

3d Trial. (*T. CXXIV.*)	4th Trial. (*T. CXXV.*)	Averages.	Remarks.
May 5.	*May* 6.		
24.416	24.833		
8.416	7.25		
14.352	14.352		
377.5	377.5		
19.134	19.134		
10.0	10.0		
899.0	916.0		
881.0	904.63		
18.0	11.37	11.5125	
44.95	45.8	45.2895	
74 471	88.482	89.566	Five pounds more coal were supplied per hour during the 4th than during the 2d trial, but the boiler took 77 pounds less of water per hour. The heating power in the 4th experiment was, to a great extent, expended on the gases of the chimney, not on the water of the boiler.
5.188	6.165	5.8428	
10.567	10.335	10.6009	
3.3905	3.3019	3.8588	
32.084	31.905	36.7982	
6197.0	5618.0		
64°.9	64°.9		
717.0	820.0		
98°.0	114.0		
494.29	430.3	521.895	
7.908	6.884	8.348	A constant falling off in the evaporative power of the boiler is here observed.
1.3098	1.139	1.3822	
1.427	1.1869		
6.9228	6.0842	6.7126	
6.637	4.863	5.8615	The coal was supplied during the period assumed for steady action more rapidly than it was burned.
9.0281	10.272	9.3404	
62°.94	64°.64		
-	-	-	The dew point apparatus had not been prepared at the date of these experiments.
334°.25	405°.79	362°.51	
326°.19	341°.79	302°.54	There is a constant increase in the temperature of the gases arriving at the chimney, due, no doubt, to the enormous coat of soot that rapidly accumulated on all the heat-absorbing surfaces.
227°.375	227°.5		
60°.0	62°.0		
30.251	30.234		
8.8303	8.806		
0.176	0.178		
0.1446	0.1509	0.145	The chimney was 41 feet high, and the draught defective; hence the slowness of the combustion.
271°.37	341°.15	297°.955	
98°.815	114°.29	74°.811	
6.9217	6.0752	6.7126	
7.9102	6.9429	7.6755	
355.56	317.98	347.445	
8.8448	7.7431	8 5885	The last experiment had the disadvantage of being performed with flues coated throughout with a thick mass of soot.
1.4049	1.4151	1.416	
5.9806	6.1307	6.1443	
Open.	Open.	-	The opening of the air plates did not produce any salutary effect on the efficiency of this coal.
U. 6	U. 12		

No. 6.

Bituminous coal from the Chesterfield Mining Company, Chesterfield county, Va.

The following statement accompanied this sample:

"WASHINGTON, *June* 29, 1842.

"GENTLEMEN: On the 24th instant, I forwarded to the navy yard at Washington five hogsheads of bituminous coal, for the purposes stated in the advertisement.

"I have the honor to inform you that this coal has been mined within the last month, and is from the pits of the Chesterfield Mining Company, situate in Chesterfield county, within twelve miles of Richmond, Va., and formerly known as the "Black Heath pits," and which have been lately purchased by English capitalists, whose general agent and manager I am.

"The coal could be delivered any where in the United States.

"I have the honor to be, gentlemen, with great respect, your obedient humble servant,

"R. I. D. GIFFORD.

"To the Hon. the BOARD OF NAVY COMMISSIONERS, *Washington.*"

In external characters, this coal is much nearer to the Midlothian than to the Clover Hill coal, last described. It was received generally in lumps of considerable size, which will, in part, account for its lowness in weight per cubic foot. Efflorescent sulphate of iron is of frequent occurrence; and carbonate and sulphate of lime are also observable at the partings. Conchoidal fractures and a resinous lustre are conspicuous along the horizontal partings. The coal appears to have been mined with a degree of care not always found in samples from the same coal region. Few or no fragments of slate were noticed. It was observed to give but little waste coal, or coke, passing through the grate, and to produce a long dense flame, without decrepitation. The powder is of a dark clove-brown color, and its streak on white earthen ware is nearly of the same tint.

The specific gravity of one specimen (*a*) was 1.2938, and that of another (*b*) 1.2839, giving the calculated weight per cubic foot 80.565 pounds.

By 43 trials in the charge box, the average weight per cubic foot was found to be 45.549 pounds, or 0.5653 of the calculated weight—the maximum being 54.375, and the minimum 40. From this average, the space required per ton is 49.178 cubic feet.

The moisture in specimen *a* was 1.094 per cent.; in specimen *b*, 1.197. Twenty-eight pounds in the steam drying apparatus lost, in two days, 0.531 pound, or 1.896 per cent.

The sulphur in *a* was 1.957 per cent.; that in *b* not ascertained.

The volatile matter in *a*, other than moisture and sulphur, was 31.739; that in *b*, other than moisture, but including sulphur, 27.353.

The ashes of *a*, by a mean of four incinerations, were 4.72 per cent.; their color, when hot, a dark blackish gray; when cold, reddish gray. Those of *b*, by the same number of incinerations, 6.13 per cent.; grayish white when hot, becoming salmon color on cooling.

The following, therefore, exhibits the composition of these two specimens, viz:

	Specimen *a*.	Specimen *b*.
Moisture	1.094	1.197
Sulphur	1.957	(not tried.)
Other volatile matter	31.739	27.353
Ashes	4.720	6.130
Fixed carbon	60.490	65.320
	100.	100.
Volatile to fixed combustible	1 : 1.795	1 : 2.3953

To compare the above results with that derived from the furnace, which exhibits the practical determination of the waste matter of the coal, it may be stated, that in burning 3,876 pounds of this coal, there were obtained 185.5 pounds of ashes, including 1.644 pound of ashes of wood, and that their weight per cubic foot was 47.29 pounds. They lost by reincineration 18.744 per cent., and became of a light ochrey-red color. The clinker, which weighed 166.75 pounds, was of moderate density, weighed 37.62 pounds per cubic foot; having a brown color on the fused surfaces, and black within; its masses large, evidently prone to spread out into sheets, with some light-colored patches diffused through it. The clinker gained in weight nearly one per cent. by calcination, leaving a dark-brown residue. The soot collected (26.25 pounds) weighed 22.7 pounds per cubic foot, and lost 28.67 per cent. by incineration, leaving a reddish-gray ash.

Hence, after the above deductions, and subtracting the ashes of wood, we have left 334.665 pounds, or 8.6343 per cent., of absolute waste.

The total volatile matter, including moisture, in two specimens tried by Dr. King, was 33.25 and 33.70, which, with the two above presented, afford a mean of 32.572. From this, deducting the moisture (1.896) obtained in the large apparatus, the remainder (30.676) may be assumed as the average of volatile combustible. Hence, in 100 parts of the raw coal, we have of—

Moisture	1.896
Volatile combustible	30.676
Earthy matter	8.634
Unvolatilizable carbon	58.794
	100.
From the above, the volatile is to the fixed combustible as	1 : 1.9166

A trial of 20 grains of specimen *a*, by the oxide of lead, resulted in producing 516.68 grains, or 25.784 times its weight of metallic lead; and this, after deducting moisture and ashes, is 27.376 of lead to 1 of combustible matter. Sixty pounds were found in the chain shop sufficient to make 9 links of 1$\frac{5}{8}$-inch chain.

The flame is large, and the fire very hot. No deleterious effect was produced on the iron. At the anchor shop, when an equal quantity was used, it produced a good hollow fire, yielded but little cinder, and gave a good welding heat, without injuring the iron. Its proportion of volatile matter is such as to adapt it to the purpose of manufacturing illuminating gas. The long and brilliant flame which it produces renders the fire of a grate exceedingly cheerful.

When thrown into the furnace already in brisk action, it produces almost instantly a copious flame, and yields a good coherent coke, of which but little passes through the grate.

The average time required to bring the boiler to steady action was 1*h*. 10*m*., (1.166 hour,) and the average weight of coke left was 10.469 pounds.

The manufacture of iron from the ore could not be advantageously carried on with this coal, without the preliminary process of coking.

TABLE CXXVII.—CHESTERFIELD

First trial—upper damper 12

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 6	4.35	73	68	142	138	79	207	-	29.82	-	-	0.10	-	-
	5.05	72	67	140	166	79	206	-	29.82	-	-	0.10	-	-
	6.30	73	67	136	218	78	228	-	29.88	0.183	8.76	0.22	-	80.50
	7.00	74	67	139	252	79	232	-	29.89	0.230	8.28	0.40	250	88.75
	7.30	74	66.5	146	318	79	238	-	29.90	0.255	8.02	0.60	·560	86.00
	8.00	73	66	166	334	79	235	-	29.92	0.240	8 18	0.47	1455	91 25
	8 30	75	65	184	366	79	236	-	29.92	0.238	8.20	0.47	2130	95.25
	9.00	73	63.5	200	363	79	235	-	29.92	0.246	8.12	0 50	2895	93.00
	9.30	74.5	64	214	374	79	235	-	29.92	0.234	8.23	0.45	3615	91.25
	10.00	76	65	232	364	80	235	-	29.92	0.240	8.17	0.45	4200	89.50
	10.10	-	-	-	-	80	235	-	-	-	-	-	-	103.75
	11.00	76	65	264	364	74	234	-	29.93	0.243	8.14	0.42	5515	85.75
	11.30	80	66	272	350	74	234	-	29.93	0.242	8.15	0.50	6190	92.25
	P. M.													
	0.00	82	69.5	288	359	73	233	-	29.93	0.228	8.30	0.42	6785	87.50
	0.30	80	67	298	364	74	233	-	29.93	0.232	8.26	0.42	7300	83.00
	1.00	81	67.5	304	348	74	232	-	29.93	0.233	8.25	0.42	7950	-
	1.30	86	69	316	356	75	233	-	29.92	0.220	8.38	0.40	8433	81.00
	2.00	83	68	315	360	75	232	-	29.92	0.218	8.40	0.35	8942	-
	2.30	85	69	317	347	75	232	-	29.94	0.216	8.42	0.36	9192	86.50
	3.00	80	65	326	323	76	232	-	29.94	0.209	8.49	0.30	9612	-
	3.10	-	-	-	-	76	-	-	-	-	-	-	9860	
	A. M.													
June 7	5.25	61	57	195	178	74	209	-	30.17	-	-	0.18	10599	-

Period of steady action, from 7*h.* 30*m.* a. m. to 2*h.* 30*m.* p. m.—7 hours. Coal supplied to the grate, 1,080 lbs.; water to the boiler, 8,632 lbs.; water to 1 of coal, 7.992.

MINING COMPANY'S COAL.

inches open ; air plates closed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet; steam pipe in chimney removed from the horizontal escape pipe.
h. m.					Wind SW., light; cloudy.
-	65.5	69	—69	-	Water at normal level.
-	64.4	68	—40	-	Commenced firing at 5*h.* 5*m.* a. m.; kindled fire in small furnace.
6.30	64.0	63	—10	-	Wood consumed 142½ lbs.; commenced charging with coal; steam blows off at 6*h.* 40*m.* a. m.; wind at 7*h.* a.
7.00	63.4	65	+20	1.325	m. NW.; cloudy.
7.30	62.6	72	80	1.642	Raining lightly; damper to small furnace closed; at 7*h.* a. m. loaded valves with a second weight, found the manome-
8.00	62.3	93	99	4.742	ter to rise to 0.300 before steam again blew off; syphon
8.30	59.5	109	130	3.576	fell to 0.30; temperature of water in boiler rose to 239°;
8.50	57.9	127	128	4.053	on removing weight, syphon rose to 1.8 inch, smoke 11
9.20	58.0	139.5	139	3.815	seconds to reach chimney top; at 9*h.* 20*m.* a. m. smoke
9.45	59.1	156	129	3.099	15 seconds to reach top of chimney; syphon 0.44; at 9*h.*
10.20					30*m.* a. m. smoke 12.5 seconds in reaching chimney top;
11.00	59.1	188	130	3.483	at 9*h.* 40*m.* a. m. smoke 13 seconds in reaching chimney
11.25	58.9	192	116	3.576	top, syphon 0.44; filled tank at 10*h.* 25*m.* a. m.
11.50	64.0	206	126	3.152	Wind NW., moderate; clear.
0.30	60.7	218	131	2.728	
-	59.4	223	116	3.444	
1.30	61.6	230	123	2.559	
-	59.8	232	128	2.697	Filled tank at 2*h.* 10*m.* p. m.
2.30	62.0	232	115	1.325	Placed 28 lbs. of this coal in drying apparatus.
-	57.1	246	91	2.225	Contents of ash pit thrown on grate; damper set to 6 inches; water 1 inch above normal level.
-	53.6	134	—31	-	Water in boiler adjusted; clinker this morning forming an almost entire crust over the back part of the grate.

RESIDUA.

	Pounds.
Clinker	67.00
Ashes	47.75
Ashes behind bridge	5.72
Total clinker and ashes	120.47
Deduct wood ashes	0.437
Total waste from coal	120.033
Coke	10.213

TABLE CXXVIII.—CHESTERFIELD

Second trial—upper damper 6

Period of steady action, from 8*h*. 20*m*. a. m. to 4*h*. 10*m*. p. m.=7*h*. 50*m*.; coal supplied to grate, 659 lbs.; water to boiler, 5,695 lbs.; hence, water to 1 of coal, for this period, is 8.639.

MINING COMPANY'S COAL.

inches open; air plates closed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet; upright steam pipe still off.
h. m.					
-	53.6	134	—31	-	Commenced firing; no fire in small furnace; wind NE., light.
7.00	51.7	125	—26	-	Wood consumed, 152½ lbs; commenced charging with coal; steam at equilibrium.
7.40	56.0	120	+50	1.340	Steam blows off at 7*h*. 10*m*.
8.20	53.0	130	92	2.755	
-	53.7	144	110	3.179	Steam all thrown out at back valve, by double weighting the front.
9.20	53.4	163	96	1.775	
-	52.5	174	88	2.156	
10.00	51.4	187	94	1.791	
-	51.3	198	84	2.702	Smoke 26.5 seconds in reaching chimney top; syphon, 0.24; wind SW.
11.00	55.3	204	93	1.828	Smoke 24.5 seconds in reaching chimney top; syphon 0.24. At 11*h*. 25*m*. smoke 23 seconds; syphon 0.23.
-	56.0	151.5	92	2.702	
0.00	53.7	209	66	0.917	At 11*h*. 45*m*. commenced drawing gases; drew in 12 minutes 100 cubic inches, which gave 0.38 grain of water.
-	55.2	214	95	2.172	
1.10	57.1	220	105	0.874	
-	58.9	230	102	2.384	Smoke 22 seconds in reaching chimney top.
2.20	58.5	235	98	1.509	
-	60.3	239	97	2.031	Drew, at 4*h*. 10*m*., in 12 minutes, 100 cubic inches of gases, which gave 0.42 grain of water.
4.10	55.7	239	-	1.604	
-	59.0	234	78	1.239	Contents of ash pit thrown on grate.
-	59.9	149	—41		
-	-	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	35.00
Ashes	38.75
Ashes behind bridge	4.02
	77.77
Deduct wood ashes	0.468
Total waste from coal	77.302
Coke	7.40
Soot	3.25

TABLE CXXIX.—CHESTERFIELD

Third trial—upper damper 6 *inches open ; air*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
June 8	5.30	70	63	212	190	74	211	-	30.22	-	-	0.12	-	-
	6.25	71	64.5	202	244	75	227	-	30.22	0.210	8.48	0.18	-	82.75
	7.00	73	65	200	256	75	231	-	30.22	0.212	8 45	0.20	173	89.00
	7.30	74	65	208	264	75	232	-	30.22	0.223	8.35	0.20	435	87.25
	8.00	75	67	230	280	72	232	-	30.22	0.213	8.41	0.20	842	-
	8.30	76	68.5	247	280	72	232	-	30.22	0.216	8.42	0.20	1342	88.75
	9.00	77	69	266	278	72	232	-	30.22	0.216	8.42	0.20	1672	-
	9.30	80	70	279	285	72	232	-	30.21	0 212	8.45	0.19	2017	87.25
	10.00	80	70.5	286	288	72	233	-	30.21	0.209	8.49	0.18	2437	93.00
	10.30	81	72	297	280	72	232	-	30.20	0.218	8.40	0 20	2872	-
	11.00	82	72	302	-	72	232	-	30.20	0.210	8.48	0.19	3207	92.50
	11.30	83	73	312	288	72	232	-	30.19	0.210	8.48	0.18	3617	-
	P. M.													
	0.00	84.5	73.5	316	318	73	233	-	30.19	0.208	8.50	0.18	3869	-
	0.30	85	74	312	322	74	232	-	30.16	0.202	8 56	0.21	4347	80.75
	1.00	85	74	310	340	74	232	-	30.16	0.203	8.55	0.20	4687	-
	1.12	-	-	-	-	-	-	-	-	-	-	-	4849	
	1.42	87	75	314	320	80	233	-	30.16	0.205	8.52	0.22	4849	86.50
	2.20	82	75.5	322	330	80	232	-	30.13	0.189	8.70	0.19	5509	-
	A. M.													
June 9	5.10	-	-	212	194	80	216	-	-	-	-	0.14	5759	-
	5.25	74.5	71	210	192	80	211	-	30.40	-	-	0.12	6409	-

Period of steady action this day, from 7*h.* 30*m.* a. m. to 1*h.* 42*m.* p m.=6*h.* 12*m.*; coal supplied to grate, 728.75 lbs.; water to boiler, 4,414 lbs.; water to 1 of coal, 6.057.

MINING COMPANY'S COAL.

plates open; steam thrown out at back valve.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	58.7	142	—21	-	Commenced firing; wind NE.; cloudy; flues swept before the experiment
6.25	60.7	131	+17	-	Wood consumed, 110½ lbs.; commenced charging with coal; steam at equilibrium.
7.00	60 6	127	25	0.748	Air plates opened at 6*h*. 37*m*. a. m.; damper set at 6 inches.
7.30	60.1	131	32	1.388	Steam escapes freely at 6*h*. 54*m*. a. m.
-	63.0	155	48	2.156	Wind SW., brisk; cloudy.
8.30	65.0	171	48	2.649	Smoke 30 seconds in reaching chimney top; wind S.; considerable volumes of smoke at chimney top at charging,
-	65.3	189	46	1.748	which continues, but gradually decreasing, for about 15
9.30	65 7	199	53	1.829	minutes; but little smoke during the intervals of stoking
10 25	66.4	206	56	2.225	or charging; wind at 9*h*. 30*m*. a. m. SSW.
-	68.4	216	48	2.305	Wind S.; clear.
11.20	68.1	220	-	1.775	Coal in drying apparatus weighs 27 lbs. 7½ oz. at 5*h*. 30*m*. a. m., June 9th.
-	69.2	229	54	2.172	Smoke 32 seconds in reaching chimney top at meridian.
-	69.4	231.5	85	1.335	Drew at 0*h*. 15*m*. p. m. 100 cubic inches of gases in 13.5 minutes, which gave water 0.76 grain, carbonic acid
0.30	70 0	227	90	2 532	3.86 grains; smoke flowing from chimney.
-	70.0	225	108	1.801	Smoke 22 seconds in reaching chimney top; syphon 0.20. This is a questionable observation, as the lower damper was probably not exactly closed. Drew at 1*h*. 30*m*.
1.42	70.9	227	87	0.613	p. m. 100 cubic inches of gases, which gave water 1.02 grain, carbonic acid 4.11 grains; no smoke from chim-
-	73.2	240	98	2.761	ney. At 2*h*. 20*m*. p. m., contents of ash pit thrown on grate, and air plates closed; at 3*h*. 20*m*. p. m., damper
-	-	-	—22		set at 3 inches.
-	69.5	135.5	—19	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	33.00
Ashes	36.00
Ashes behind bridge	3.38
Total ashes and clinker	72.38
Deduct wood ashes	0.338
Total waste from coal	72.042
Coke	10.127

TABLE CXXX.—CHESTERFIELD

Fourth trial—upper damper 12 *inches open;*

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
June 9	5.30	74.5	71	210	192	80	211	-	30.02	-	-	0.12	-	-
	6.55	77	72	203	260	80	225	-	30.02	0.180	8.80	0.23	-	91.25
	7.15	77	71.5	200	293	80	231	-	30.00	0.203	8.55	0.23	-	87.50
	....	....	....	....	....	....	....	....	....	....	.....			
	8.00	78	74	194	390	80	232	-	30.00	0.226	8.32	0.35	510	-
	8.30	80	73	200	430	80	234	-	30.00	0.234	8.23	0.40	860	92.75
												.....	....	....
	9.00	81	74	210	426	80	233	-	30.00	0.220	8.37	0.33	1680	90.50
	9.30	83	75	214	425	80	233	-	29.99	0.218	8.40	0.32	1872	-
	10.00	85	75	226	376	80	233	-	30.00	0.222	8.36	0.33	2285	97.50
	10.45	86	76.5	226	395	82	231	-	29.99	0.208	8.50	0.30	3052	91.25
	11.45	88	77	238	404	81	233	-	29.99	0.222	8.36	0.35	3877	105.75
	P. M. 0.15	89	77	216	470	81	233	-	29.97	0.222	8.36	0.44	4292	92.00
	0.45	90	77	255	428	81	233	-	29.97	0.201	8.57	0.30	4977	-
	....	....	....	....	....	...	....	....	....	....	.....			
	1.20	92	78	262	335	81	232	-	29.96	0.193	8.66	0.28	5539	104.25
												.....	....	....
	2.30	94	80	278	320	87	230	-	29.93	0.177	8.82	0.23	5949	-
June 10	A. M. 4.15	72	79	204	184	87	214	-	29.84	-	-	0.14	6219	-
	4.50	-	-	-	-	-	210	-	-	-	-	-	6676	-

Period of steady action this day, from 8*h.* 30*m.* a. m. to 1*h.* 20*m.* p. m.=4*h.* 50*m.*; coal supplied, 581.25 lbs.; water delivered to boiler, 4,679 lbs.; hence, water to 1 of coal for this period, 8.049.

MINING COMPANY'S COAL.

air plates open; steam thrown into chimney.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	69.5	135.5	—19	-	Commenced firing; wind SW., brisk; clear.
6.55	69.9	126	+32	-	Wood consumed, 130.75 lbs.; commenced charging with coal; air plates opened.
7.15	69.1	123	62	-	Removed second weight from safety valve; steam blows off.
-	72.5	116	158	1.801	
8.30	70.3	120	196	1.854	
9.00	71.4	129	193	4.344	At 9*h*. 27*m*. smoke 16.5 seconds in reaching chimney top, syphon 0.28.
-	72.2	131	192	1.017	At 9*h*. 50*m*. smoke 20 seconds in reaching chimney top, syphon 0.27.
10.15	71.5	141	143	2.188	At 9*h*. 57*m*. commenced drawing gases; drew in 8.5 minutes 100 cubic inches, which gave water 0.94 grain; carbonic acid 4.20 grains; dew point at 10*h*. 40*m*. a. m. 75°.5.
10.45	73.4	140	164	2.709	
11.45	73.5	150	171	2.185	Filled tank at 11*h*. 30*m*.; commenced drawing gases at 11*h*. 32*m*.; drew in 15 minutes 80 cubic inches, (smoke flowing all the time,) which gave 1.03 grain water, and 4.25 grains carbonic acid.
0.15	73.2	157	237	2.199	
-	73.0	165	195	3.629	Drew gas again, from 1*h*. 3*m*. to 1*h*. 14*m*. = 11 minutes, drew 100 cubic inches, (no smoke from chimney,) which gave water 0.98 grain; carbonic acid 3.23 grains, and oxygen 14.44 cubic inches.
1.20	73.8	170	103	2.552	
-	76.1	184	80	0.931	Filled tank at 2*h*. 25*m*. p. m.; contents of ash pit thrown on grate, and air plates closed.
-	61.1	132	—30		
-	-	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds
Clinker	31.75
Ashes	46.25
Ashes behind bridge	3.63
Total clinker and ashes	81.63
Deduct wood ashes	0.401
Total waste of coal	81.229
Coke	14.185
Soot	22.60

TABLE CXXXI.—DEDUCTIONS FROM

Experiments on Chesterfield

	Nature of the data furnished by the respective tables.	1st Trial. (Table CXXVII)	2d Trial. (Table CXXVIII)
		June 6.	*June 7.*
1	Total duration of the experiment, in hours	24.833	21.0
2	Duration of steady action, in hours	7.0	7.833
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	15.0	10.0
7	Total weight of coal supplied to grate, in pounds	1335.25	941.50
8	Pounds of coal actually consumed	1325.037	931.10
9	Pounds of coal withdrawn and separated after trial	10.213	7.40
10	Mean weight, in pounds, of one cubic foot of coal	44.6083	47.075
11	Pounds of coal supplied per hour, during steady action	154.286	84.0
12	Pounds of coal per square foot of grate surface, per hour	10.965	5.97
13	Total waste, ashes and clinker, from 100 pounds of coal	9.059	8.2755
14	Pounds of clinker alone, from 100 pounds of coal	5.039	3.7234
15	Ratio of clinker to the total waste, per cent.	55.627	44.992
16	Total pounds of water supplied to the boiler	10599.0	7445.0
17	Mean temperature of water, in degrees Fahrenheit	76°.2	75°.8
18	Pounds of water supplied at the end of experiment, to restore level	739.0	317.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	99.0	42.0
20	Pounds of water evaporated per hour, during steady action	1233.14	725.77
21	Cubic feet of water per hour, during steady action	19.33	11.61
22	Pounds of water per square foot of heated surface per hour, by one calculation	3.266	1.922
23	Pounds of water per square foot, by a mean of several observations	3.253	1.972
24	Water evaporated by one of coal, from initial temp. (a) final result	7.9243	7.925
25	Water evaporated by one of coal, from initial temp. (b) during steady action	7.992	8.639
26	Pounds of fuel evaporating one cubic foot of water	7.8871	7.8865
27	Mean temperature of air entering below ash pit, during steady pressure	78°.11	76°.17
28	Mean temperature of wet bulb thermom., during steady pressure	66°.53	62°.8
29	Mean temperature of air, on arriving at the grate	213°.67	264°.07
30	Mean temperature of gases, when arriving at the chimney	347°.93	322°.47
31	Mean temperature of steam in the boiler	233°.93	231°.67
32	Mean temperature of attached thermometer	75°.0	73°.0
33	Mean height of barometer, in inches	29.921	30.231
34	Mean number of volumes of air in manometer	8.233	8.387
35	Mean height of mercury in manometer	0.234	0.2188
36	Mean height of water in syphon draught gauge	0.433	0.2364
37	Mean temperature of dew point, by calculation	60°.55	55°.02
38	Mean gain of temperature by the air before reaching grate	165°.56	187°.90
39	Mean difference between steam and escaping gases	123°.69	93°.84
40	Water to one of coal, corrected for temperature of water in cistern and boiler	7.9062	7.9156
41	Water to one of coal, from 212°, corrected for temperature of water in cistern and boiler	8.9502	8.9814
42	Pounds of water, from 212°, to one cubic foot of coal	398.36	422.80
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	9.8417	9.7918
44	Mean pressure, in atmospheres, above a vacuum	1.4666	1.4244
45	Mean pressure, in pounds per square inch, above atmosphere	6.9032	6.2675
46	Condition of the air plates at the furnace bridge	Closed.	Closed.
47	Inches opening of damper, (U. upper)	U. 12	U. 6

TABLES CXXVII, CXXVIII, CXXIX, CXXX.

Mining Company's coal,

3d Trial. (Table CXXIX.)	4th Trial. (Table CXXX.)	Averages.	Remarks.
June 8.	*June* 9.		
23.916	23.833		
6.20	4.883		
14.07	14.07		
377.5	377.5		
18.75	18.75		
9.0	9.0		
787.75	852.75		
777.623	838.615		
10.127	14.135	10.469	
43.76	47.37	45 7683	
117.54	120.267	119.023	
8.354	8.548	8.4592	
9.2664	9.674	9.0687	
4.2244	3.7681	4.1887	
45.599	38.903	46.280	The highest proportion of clinker was produced on the 1st trial, when the combustion was most rapid.
6409.0	6676.0		
74°.1	81°.3		
900.0	477.0		
83.0	56.0		
711.935	968.136	909.745	
11.39	45.49	14.467	The rapid evaporation on the 1st trial was favored by the cleanness of the flues, and the rapid combustion by the prevalence of a northwest wind, favoring a strong draught.
1.885	2.565	2.4095	
1.887	2.602		
8.135	7.8939	7.9605	
6.057	8.049	7.684	
7.6829	7.9175	7.8135	
80°.18	84°.44		
70°.57	75°.4		
277°.07	223°.22	252°.01	
291°.54	416°.0	344°.48	
232°.14	232°.77		
77°.0	81°.0		
30.183	29.99		
8.465	8.3855		
0.2112	0.2192		
0.1958	0.3312	0.2991	
66°.58	72°.32		
196°.87	138°.78	172°.28	
62°.6	174°.75	113°.72	
8.1113	7.8636	7.9492	
9.198	8.8637	8 9983	
402.51	419.87	410.89	
10.1374	9.8131	9.896	It appears that burning with the air plate open caused an increase of efficiency in the combustible matter of this coal, amounting to 1.5 per cent.
1.4142	1.4439	1.4373	
6.1176	6.5557	6.461	
Open.	Open.		
U. 6	U. 12		

No. 7.

Bituminous coal of average size, sent by the Midlothian Coal Co, Va.

This sample, together with one in the state of lumps, is referred to in the following letter:

"RICHMOND, *June* 23, 1842.

"SIR: Above I hand you a bill of lading for ten hogsheads Midlothian coal—five being screened coal, and five average coal—designed for trial for the steam service. The average coal is about 8 per cent. heavier, and about 15 per cent. cheaper, than the screened coal; and consequently it is of importance to the Government if this description of coal shall be found suitable for the naval steam service, particularly as any quantity of that kind of coal can always be obtained.

"The Midlothian mines lie about thirteen miles west of Manchester, are connected with tide water just below Manchester by a railroad, where the coal is shipped in vessels carrying less and up to 7,000 bushels. This coal has been extracted from the mines during the present year, and can be shipped at any of our cities on the Atlantic coast, or points where schooners can navigate on the Mississippi and the Gulf of Mexico.

Most respectfully, yours, "A. S. WOOLDRIDGE,

"*President of the Midlothian Coal Mining Co.*

"Com. KENNON, *Comdt. of the Navy Yard, W. C.*"

This sample exhibits the main partings inclined to the surfaces of deposition in an angle of about 80° or 81°. The planes of both the main and cross partings are marked with scales of carbonate of lime.

In the course of eighteen months, specimens not exposed to any other moisture than that in the atmosphere of a dry apartment, have become almost entirely disintegrated by the efflorescence of the sulphuret into sulphate of iron. This circumstance abundantly indicates one of the impurities of the coal, and points to its probably becoming heated if exposed in large quantities to the influences of the air for any very protracted period.

The coal produces on a white ground a brown streak, and its powder is also brown.

The specific gravity of two specimens (*a* and *b*) was found to be, respectively, 1.3006 and 1.2882, from which the calculated weight of one cubic foot is 80.895 pounds.

The weighing and measuring of forty-two charges, of which the least contained 46.25, and the greatest 58.125 pounds per cubic foot, resulted in establishing the average of the whole at 54.044 pounds, which is 0.668 of the above calculated weight. The space for stowing one ton is 41.448 cubic feet.

The analyses of the two specimens above referred to afforded the following results, viz:

	Specimen *a*.	Specimen *b*.
Moisture	0.997	0.765
Sulphur	(not examined)	0.057
Other volatile matter	31.093	30.217
Earthy matter	4.800	4.375
Fixed carbon	63.110	64.585
	100.	100.
Volatile to fixed combustible	1:2.0297	1:2.133

The volatile matter, including moisture, in two specimens examined by Dr. King, was found to be 33.251 per cent.; which, combined with the above, give the mean for four specimens of 32.251 per cent. of products volatilizable at redness.

The moisture expelled by drying 28 pounds for two days was 11 ounces, or 2.455 per cent.

The combustion of 4,506.39 pounds of this coal yielded—

278.39 pounds of ashes,	weighing	53.8	pounds per	cubic foot.
402 pounds of clinker,	"	37.50	"	"
28 pounds of soot,	"	19.06	"	"

The ashes lost by reincineration 10.09, the clinker 0.968, and the soot 36.66 per cent. Making these reductions, and subtracting the ashes of wood consumed in raising steam, (2.36 pounds,) the remainder is 664.105 pounds, or 14.737 per cent. of the coal actually consumed.

The clinker is dark brown, or black, with portions of lighter colored shaly matter disseminated through it. The masses are large and porous. This circumstance, together with the minute subdivision in which the sample was found, caused much clogging of the grate; demanded frequent use of the slice bar to keep it moderately free; and required the contents of the ash pit to be several times returned to the grate, to prevent the loss of much small coke and coal.

When completely calcined, the clinker becomes reddish brown, or *dark red gray*. After reincineration, the ashes are of a deeper red than the clinker; and the residue of the soot is of a dull brick-red tint, while the ashes from analysis are of a blackish-gray color.

The experiments on the entire sample may be represented as giving the following composition of this coal:

Moisture	2.455
Other volatile matter	29.796
Earthy matter	14.737
Fixed carbon	53.012
	100.

Hence the volatile to the fixed combustible is 1 : 1.78.

With oxide of lead, the reductive power of specimen *b* was found to be 27.344, which, after deducting earthy matter and moisture, gives for 1 of *combustible matter* 29.027.

The action of this sample in smith work was proved only in the anchor shop, where it was used in heating large bars about three inches square. It worked well, forming a good hollow fire, produced a light coke, and gave a large amount of cinder.

In an office grate it exhibited, when thrown on a mass of ignited coke, an immediate development of brilliant flame; and though, by the rapid absorption of caloric by the gas and vapors produced, the heat of the fire was necessarily in some degree checked, the flame did not wholly cease, as often happens, while the vapors of water and tar were passing off. When undergoing the partial fusión which attends the rapid evolution of gas and vapor, it sends out jets of white flame of great brilliancy. This, together with the amount of its gaseous products, marks its adaptation to the purposes of producing illuminating gas.

The average length of time required to bring the boiler into steady action was 1.516 hour; and the weight of coke left unburnt on the grate was, on an average of five trials, 6.442 pounds.

TABLE CXXXII.—MIDLO

First trial—upper damper 6 inches

Date.	Hour.			…PERATURES OF THE Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
May 23	5.15	60	–	–	–	–	162	–	29.79					
	5.35	62	56	–	–	[illegible]	–	–	29.79	–	–	–	–	–
	6.40	60	57	128	212	65	201	–	29.82	–	–	0.16	–	–
	7.45	62	57.5	140	–	65	227	–	[illegible]	0.159	9.00	0.17	–	–
	8.00	63	58	142	178	65	228	–	29.84	0.165	8.94	0.17	–	110.50
	9.00	64.5	59.5	160	236	65	228	–	29.84	0.173	8.86	0.19	265	–
	9.30	66	60	166	240	65	228	–	29.84	0.168	9.01	0.20	420	112.[illegible]
	10.10	67	61	184	[illegible]	66	230	–	29.86	0.171	8.88	0.18	760	–
	11.00	69	62	212	240	65	230	–	29.86	0.170	8.89	0.17	1100	104.75
	P. M. 0.00	72	63	238	245	65	230	–	29.85	0.165	8.94	0.19	1696	–
	0.25	73	62	244	248	65	229	–	29.85	0.165	8.94	0.19	1869	109.[illegible]
	0.45	73.5	62.5	252	259	65	[illegible]	–	[illegible]	0.170	8.89	0.20	[illegible]	–
	1.20	74	62.5	262	258	65	229	–	29.83	0.163	8.96	0.20	2455	–
	1.50	75	63	273	256	65	230	–	29.82	0.162	8.97	[illegible]	2625	–
	2.30	76	[illegible]	286	250	66	229	–	29.81	0.157	[illegible]	0.20	2965	105.[illegible]
	2.55	80	64	294	264	66	230	–	29.79	0.165	8.94	0.21	3045	–
	3.30	79	65.5	292	259	66	230	–	29.79	0.160	8.99	0.22	3285	109.00
	4.00	80.5	67.5	294	266	66	230	–	29.79	0.163	8.96	0.21	3605	–
	4.30	79.5	66	298	275	67	230	–	29.79	0.159	[illegible]	0.21	3360	–
	5.00	82	67	296	266	67	230	–	29.79	0.159	9.00	0.20	4025	–
	5.35	83.5	67	302	274	72	230	–	29.78	0.160	[illegible]	0.22	4360	[illegible]
	6.00	[illegible]	67	306	268	72	230	–	29.79	0.163	8.96	0.20	4525	–
	6.35	80	66	310	264	72	230	–	29.78	0.162	8.97	0.20	4780	–
	7.00	76	65	314	264	72	229	–	29.78	0.161	[illegible]	0.18	5040	107.25
	7.15	–	–	316	264	72	228	–	29.78	0.147	9.12	0.17	5450	–
May 24	A. M. 5.10	61	57	206	[illegible]	72	214	–	[illegible]	–	–	0.11	[illegible]	–
	5.45	61.5	57.5	–	–	72	209	–	–	–	–	–	6807	–

The period of steady action this day extends from 11*h*. a. m. to 7*h*. p. m.=8*h*.; the weight of coal supplied to the grate in that time was 538 lbs.; of water to the boiler, 3,940 lbs.; water to 1 of coal, 7.323.

THIAN (AVERAGE) COAL.

open; air plates open; coking plate on.

Time each charge was on grate.					
h. m.					
-	[illegible]	-	-	-	Commenced firing.
-	54.4	68	+11	-	Wood consumed, 215¾ lbs.
-	53.8	78	-	-	Commenced charging; steam at equilibrium.
9.00	54.0	79	—50	-	Steam begins to blow off.
-	55.8	95.6	+ 7	0.702	At 9h. 15m. air plates opened.
9.30	56.4	101	12	0.631	Damper reduced to 6 inches.
-	56.9	117	10	1.351	
11.00	57.5	143	10	1.081	
-	57.5	166	15	1.676	
0.25	56.7	172	19	1.049	
-	56.7	178.5	29	0.911	
-	55.5	186	20	1.221	
-	55.9	196	26	0.901	
2.30	53.4	210	21	1.351	Coal passes in considerable quantities through the grate.
-	55.2	204	34	[illegible]	The wet and dry bulb thermometers first placed in air port, previously a few feet distant.
3.45	58.5	213	29	[illegible]	Coal clogs the grate, requiring frequent opening from below.
-	[illegible]	213.5	36	[illegible]	Placed 28 lbs. of this coal in the kettle to dry.
-	59 1	216.5	40	1.351	Smoke 33 seconds in reaching chimney top at 4h. 50m.
-	59.8	214	36	0.874	Filled tank at 5h. 15m. p. m.
5.35	59.4	218.5	44	1 521	The coal burned to day chiefly fine, mixed with small lumps. Not much smoke from chimney to-day.
-	60 7	226	38	1.049	
-	58.9	230	34	1.158	Smoke 29 seconds in reaching chimney top.
7.00	[illegible]	238	35	1.653	
-	-	-	36	-	Contents of ash pit thrown on grate.
-	53.6	145	—20		
-	54.0	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	71.50
Ashes	54.25
Ashes behind bridge	1.60
	127.35
Deduct wood ashes	0.662
Total waste from coal	126.688
Coke	5.60

TABLE CXXXIII.—MIDLO

Second trial—upper damper 12 inches

Date.			eter.	Temperatures of the air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
May 24	5.50	61	57	205	180	72	208	–	29.92	–	–	0.12	–	–
	7.35	71	64	188	260	72	226	–	29.95	0.154	9.04	0.15	–	–
	8.10	68.5	59	198	260	72	226	–	29.96	0.168	8.91	0.19	–	111.50
	9.10	69	60	200	308	72	226	–	29.97	0.183	8.76	0.23	340	–
	9.50	71	61.5	210	304	72	230	–	29.97	0.181	8.78	0.20	600	111.00
	10.15	72	61.5	222	310	72	230	–	29.96	0.175	8.84	0.22	1000	–
	11.00	74	61.5	226	316	72	230	–	29.95	0.181	8.78	0.25	1295	–
	11.25	75	62	228	320	72	230	–	29.94	0.183	8.76	0.24	1585	105.25
	P. M.													
	0.15	76	61.5	236	332	72	230	–	29.94	0.179	8.80	0.24	2060	–
	0.30	75	60.5	243	338	73	231	–	29.94	0.178	8.81	0.25	2355	106.00
	1.10	80	63.5	254	335	72	231	–	29.93	0.175	8.84	0.24	2605	–
	1.30	79	63.5	256	332	73	231	–	29.93	0.169	8.90	0.24	2690	–
	2.00	79.5	64	264	318	73	231	–	29.92	0.172	8.87	0.24	[illegible]	107.00
	2.55	80	64	270	314	73	231	–	[illegible]	0.176	8.84	0.21	3330	–
	3.25	79.5	64.5	274	326	74	232	–	29.89	0.171	8.88	0.21	3745	–
	3.45	80	65	271	326	74	230	–	29.89	0.165	8.95	0.22	4005	104.75
	4.25	82	65.5	276	319	75	231	–	29.90	0.162	8.98	0.22	4235	–
	4.55	81	65	282	313	75	231	–	[illegible]	0.163	8.96	0.21	4405	104.75
	5.35	81	66	283	312	75	230	–	29.89	0.172	8.87	0.24	4650	–
	6.00	81	66	[illegible]	318	75	231	–	29.89	0.172	8.87	0.21	[illegible]	104.25
	6.35	81	66	295	318	75	231	–	29.89	0.161	8.98	0.20	5470	–
	6.45	78	[illegible]	299	304	75	229	–	29.89	0.155	9.04	0.20	5860	–
	A. M.													
May 25	4.58	63	55.5	220	200	75	220	–	29.91	–	–	0.12	5860	–
	5.20	66	58	224	188	75	210	–	29.94	–	–	0.14	6480	–

Period of steady action, from 11*h*. 25*m*. a. m. to 6*h*. p. m. = 6*h*. 35*m*.; coal supplied to grate, 526.75 lbs.; water to boiler, 3,315 lbs.; water to 1 of coal, 6.253.

THIAN (AVERAGE) COAL.

open; air plates open; coking plate on.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between, steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 12.1875 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	53.6	144	—22	-	Commenced firing.
-	59.9	117	+34	-	Wood consumed, 155 lbs.; commenced charging; steam at equilibrium.
8.10	53.0	129.5	34	-	Steam blows off; damper set at 12 inches; air plates opened at 8*h.* 20*m.* a. m.
-	53.7	131	82	0.901	Coal in drying apparatus weighed 27 lbs. 12 oz.
9.50	55.0	139	74	1.033	A small portion of the third charge was thrown on the grate with the second.
-	54.0	150	80	2 543	
-	53.0	152	86	1.042	
11.25	54.0	153	90	1.844	Smoke 26 seconds in reaching chimney top.
-	52.0	162	102	-	Tank partly filled at m.
0.20	51.0	168	107	1.882	
-	54.0	174	104	0.993	
-	54.0	177	101	0.675	
1.30	54.0	184.5	87	1.271	
-	55.0	190	83	1.156	
-	56.0	194.5	94	2.199	
3.45	57.1	191	96	2.066	Filled tank at 4*h.* 15*m.*
-	57.0	194	88	0.914	
5.05	56.6	201	82	0.901	Smoke 23.5 seconds in reaching chimney top; syphon 0.22.
-	58.5	202	82	0.973	
6.00	58.5	203	87	1.589	Less fine coal in that burned to-day than yesterday.
-	58.5	214	87	2.588	Air plates closed, and contents of ash pit thrown on grate.
-	58.0	221	75	-	Water in boiler left at 1.5 inch above normal level.
-	48.7	157	—20	-	Water in boiler found 1.25 inch below normal level.
-	51.7	158	—22	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	72.00
Ashes	47.50
Ashes behind bridge	1.60
Total clinker and ashes	121.10
Deduct wood ashes	0.324
Total waste from coal	120.776
Coke	3.37

TABLE CXXXIV.—MIDLO

Third trial—lower damper 12 inches

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
May 25	5.50	68	60	216	188	75	210	-	29.97	-	-	0.14	-	-
	7.20	67	57	202	214	74	226	-	29.96	0.147	9.14	0.15	-	-
	7.40	68	56	200	-	74	227	-	29.96	0.173	8.86	0.17	-	111.00
	....	......	......	......	......	......	......	......	....	....	....			
	8.20	65	55	194	420	74	230	-	29.97	0.186	8.72	0.19	415	-
	8.40	66	55.5	200	440	74	231	-	29.97	0.190	8.69	0.22	595	112.50
	9.10	66	54	209	432	74	232	-	29.99	0.196	8.62	0.23	920	-
	9.45	68	54 5	217	420	74	231	-	29.99	0.187	8.72	0.22	1400	-
	10.00	68	55	217	420	74	230	-	29.99	0.195	8.64	0.20	1560	108.25
												......	......	....
	10.50	69	56	230	450	70	231	-	29.99	0.189	8.70	0.20	2055	104.50
	11.20	68	56	242	428	70	232	-	30.00	0.194	8.65	0.20	2455	-
	P. M.													
	0.00	70	58	254	466	70	230.5	-	29.98	0.187	8.72	0.20	3022	106.75
	0.30	69.5	56.5	258	432	70	231	-	29.98	0.181	8.78	0.20	3365	-
	1.00	70	57.2	262	440	70	232	-	29.98	0.192	8.66	0.21	3705	-
	1.30	70	57	268	440	70	231	-	29.94	0.171	8.84	0.20	4045	107.25
	2.00	73	60	268	474	70	231	-	29.95	0.178	8.81	0.19	4360	-
	2.30	73	60	269	500	71	232	-	29.95	0.189	8.70	0.20	4600	104.75
	3.00	74	60.5	273	446	70.5	230	-	29.95	0.181	8.78	0.21	4835	-
	3.30	76	61	276	568	71	231	-	29.95	0.179	8.80	0.21	5170	104.50
	4.00	73 5	60.5	276	460	71	232	-	29.94	0.181	8.78	0.20	5420	-
	4.30	75	61	276	454	71	231	-	29.95	0.179	8.80	0.20	5755	-
	5.00	75	62	276	460	72	231	-	29.95	0.179	8.82	0.20	6015	104.50
	5.30	73.5	62	274	500	71	231	-	29.95	0.186	8.73	0.21	6255	-
	6.00	78	64	284	440	73	232	-	29.95	0.185	8.74	0.22	6760	109.50
												......	......	....
	6.30	76	64	286	420	71	232	-	29.95	0.175	8.85	0.19	7015	-
	....	......	......	......	......	......	......	......	....	....	....			
	6.40	-	-	290	420	71	229	-	29.95	0.161	8.98	0.19	7565	-
	A. M.													
May 26	4.40	63	59	210	-	72	214	-	29.96	-	-	0.15	7573	-
	5.10	65	60	210	-	72	212	-	29.97	-	-	0.14	7825	-

Period of steady action, from 10*h.* 0*m.* a. m. to 6*h.* 0*m.* p. m. = 8*h.*; coal to grate for that time, 741.75 pounds; water to boiler, 5,200 pounds; water to one of coal, 7.01.

THIAN (AVERAGE) COAL.

open; air plates open; coking plate on.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 12.1875 square feet; length of circuit of heated gases 59.5 feet; height of chimney 41 feet.
h. m.					
-	54.3	148	— 22	-	Commenced firing.
-	48.8	135	— 12	-	Wood consumed, 121 pounds; commenced charging; steam at equilibrium.
7.40	45.7	132	-	-	Lower damper opened to 12 inches; steam blows off at 7*h*. 40*m*. a. m.
-	45.8	129	+190	2.309	
8.40	46.0	134	209	1.557	Air plates opened.
-	42.4	143	200	2.249	
-	39.5	149	189	2.347	Smoke 12 seconds in reaching chimney top.
10.00	43.2	149	190	2 445	Commenced drawing gases at 10*h*. 12*m*. a. m.; drew 100 cubic inches, which gave 0.45 grain water; filled tank at 10*h*. 40*m*. a. m.
10.50	44.9	161	219	2.594	
-	45.7	174	196	3.485	
0.00	48.8	181	235.5	3.691	
-	45.0	188.5	201	2.995	
-	46 25	192	208	2.969	
1.18	46.5	198	209	2.969	
-	51.1	195	243	2.627	Smoke 13 seconds in reaching chimney top.
2.30	51.1	196	268	2 096	
-	51.0	199	216	2.052	
3.30	51.3	200	237	2.926	
-	51 5	202.5	228	2.183	
-	52.0	201	223	2.926	
5.00	54.0	201	229	2.271	Filled tank at 5*h*. 20*m*. p. m.
-	54.0	200.5	269	2.096	Coal in the drying apparatus weighed 27 pounds 5 ounces.
6.00	56.2	204	208	2.410	
-	57.2	210	188	2.227	Contents of ash pit thrown in grate; lower damper set at 6 inches.
-	-	-	191	-	Air plates closed; water in boiler left at 1.5 inch above normal level.
-	55.8	147	-	-	Water 0.45 inch below normal level.
-	56.4	145	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	110.00
Ashes	47.00
Ashes behind bridge	2.00
	159.00
Deduct wood ashes	0.371
Total waste from coal	158.629
Coke	2.25

TABLE CXXXV.—MIDLO

Fourth trial—lower damper 12

Period of steady action, from 8*h*. a. m. to 2*h*. p. m. = 6*h*.; coal supplied to grate for that time, 550.5 pounds; water to boiler, same time, 4,485 pounds; water to one of coal, 8.147.

THIAN (AVERAGE) COAL.

inches open ; air plates closed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 15.1375 square feet; length of circuit of heated gases 59.5 feet; height of chimney 41 feet.
h. m.					
-	55.7	142	— 30	-	Commenced firing; water at normal level at 212°.
6.40	56.9	137	-	-	Wood consumed, 110.75 pounds; commenced charging with coal; steam at equilibrium; blowing off at 7*h*.
7.00	55.7	137	+103		
-	59.3	126	142	1.777	Smoke 13 seconds in reaching chimney top.
8.00	56.0	125	160	2.996	
-	56.4	128	211	1.811	
9.20	55.9	137	204	2 683	
-	54.5	145	219	2.613	
-	55 3	152	229	3 066	
10 00	55 3	159	239	2 996	Smoke 11 seconds in reaching chimney top.
-	56 2	166	2[illegible]9	1.568	Filled tank; water 0.4 inch below normal level.
-	57.6	176	241	3.972	Smoke 12 seconds in reaching chimney top; water brought to proper level.
11.45	58.9	184	185	2.717	
-	58.9	198	210	2 927	
0.50	59.8	212	249	3.310	
-	60.0	213	189	1.846	
2.00	62.8	217	192	1.742	The coal of this and the preceding experiment about the same character; contents of ash pit thrown on grate, and damper reduced to six inches; filled tank at 5*h*. 5*m*. p. m.
-	63.0	210	178	2.961	
-	63.2	122			
-	61.6	117	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	74.50
Ashes - - - - - - - - - - -	53.25
Ashes behind bridge - - - - - - - -	1.70
Total clinker and ashes - - - - - - - -	129.45
Deduct wood ashes - - - - - - - - -	0.34
Total waste from coal - - - - - - - -	129.11
Coke - - - - - - - - - - -	10.872

TABLE CXXXVI.—MIDLO

Fifth trial—upper damper 12

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
May 27	5.40	68	64	190	-	-	205	-	29 89	-	-	0 14	-	-
	6.00	69	65	186	173	76	202	-	29.91	-	-	0.14	-	-
	7.00	69	64	175	318	76	226	-	29.91	0.213	8.45	0.15	-	108.75
	7.30	67	64	174	394	76	229	-	29.91	0.216	8.50	0 20	170	108.00
	8.00	70	66	178	214	76	229	-	29.91	0.213	8 44	0.21	505	-
	8.40	71	66	182	260	76	229	-	29.92	0.213	8.41	0.20	780	-
	9.00	72	66	188	276	76	228	-	29 92	0.223	8.34	0.21	950	-
	9.30	74	66	194	288	78	229	-	29.92	0 222	8.36	0.23	1290	105 25
	10.00	75	65	201	298	78	229	-	29.93	0.210	8.47	0.23	1625	-
	10.30	76	65	208	300	78	230	-	29 90	0.223	8.35	0.23	1890	110.25
	11.00	77	65	218	310	78	229	-	29.90	0.223	8 35	0.26	2475	-
	11.30	78	65	230	308	78	-	-	29.90	0.222	8.36	0.22	2780	106.75
	P. M.													
	0.00	81	67	240	310	78	227	-	29.91	0.220	8.38	0 25	3250	-
	0.30	79	66	250	314	78	228	-	29.91	0 222	8 30	0.25	3575	104.25
	1.15	80	65	260	302	78	229	-	29.91	0.202	8.55	0.23	4255	-
	1.30	81	67	264	280	77	229	-	29 90	0.213	8 45	0.22	4300	109 00
	2.00	89	70	282	280	77	230	-	29.90	0.210	8 49	0.23	4710	108.00
	2.40	84	68	283	304	77	229	-	29.90	0.197	8.62	0.21	5370	-
	A. M.													
May 28	5.15	65	62	202	180	76	210	-	29.97	-	-	0.11	5920	-
	5.45	64	61.5	-	-	76	201	-	-	-	-	-	6302	-

Period of steady action, from 9*h*. 30*m*. a. m. to 2*h*. p. m. = 4*h*. 30*m*.; coal supplied to grate, 588.25 lbs.; water to boiler, 3,420 lbs.; water to 1 of coal during this period, 8.750.

THIAN (AVERAGE) COAL.

inches open; air plates closed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 15.4375 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	122			
-	61.6	117	—29	-	Commenced firing: dew point, by observation, 60°.7 at 6*h.* 30*m.*
7.15	61.0	106	+92	-	Wood consumed, 166½ lbs.; commenced charging with coal; steam blows off.
7.30	62.2	107	165	0.901	Upper damper at 12 inches.
-	63.8	108	15	1.775	
-	63.3	111	31	1.093	
-	62.8	116	48	1.351	
9.30	61.8	120	59	1.801	Smoke 21 seconds in reaching chimney top at 9*h.* 25*m.*; syphon 0.21.
-	59.5	126	69	1.775	
10.30	59.1	132	70	1.404	Smoke 21 seconds in reaching chimney top; syphon 0.24.
-	58.5	141	81	3.099	Smoke 21 seconds in reaching chimney top; syphon 0.22.
11.20	58.1	152	-	1.616	Smoke 20 seconds in reaching chimney top; syphon 0.25.
-	60.3	159	83	2.702	Smoke 19 seconds in reaching chimney top; syphon 0.24.
0.30	59.4	171	86	1.509	
-	57.1	180	73	-	Smoke at 0*h.* 45*m.* 21 seconds in reaching chimney top; syphon 0.22.
1.25	60.3	183	51	1.921	
2.00	62.2	193	50	2.172	
-	60.7	199	75	2.622	Contents of ash pit thrown on grate, and damper reduced to 6 inches.
-	60.0	137	—30		
-	59.7	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	74.00
Ashes	58.25
Ashes behind bridge	1.60
	133.85
Deduct wood ashes	0.51
Total waste from coal	133.34
Coke	9.37
Soot	28.00

TABLE CXXXVII.—DEDUCTIONS FROM TABLES

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (Tab. CXXXII.)	2d Trial. (Tab. CXXXIII.)
		May 23.	*May* 24.
1	Total duration of the experiment, in hours	24.167	23.667
2	Duration of steady action, in hours	8.000	6.583
3	Area of grate, in square feet	12.1875	12.1875
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	16.237	16.237
6	Number of charges of coal supplied to grate	8.0	8.0
7	Total weight of coal supplied to grate, in pounds	865.5	854.5
8	Pounds of coal actually consumed	859.63	851.128
9	Pounds of coal withdrawn and separated after trial	5.97	3.372
10	Mean weight, in pounds, of one cubic foot of coal	54.093	53.4[illegible]5
11	Pounds of coal supplied per hour, during steady action	67.25	80.01
12	Pounds of coal per square foot of grate surface, per hour	5.517	6.565
13	Total waste, ashes and clinker, from 100 pounds of coal	14.738	14.16
14	Pounds of clinker alone, from 100 pounds of coal	8.2722	8.4264
15	Ratio of clinker to the total waste, per cent.	56.174	59.460
16	Total pounds of water supplied to the boiler	6307.0	6480.0
17	Mean temperature of water, in degrees Fahrenheit	68°.1	73°.5
18	Pounds of water supplied at the end of experiment, to restore level	857.0	620.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	116.0	82.0
20	Pounds of water evaporated per hour, during steady action	492.5	503.57
21	Cubic feet of water per hour, during steady action	7.88	8.057
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.304	1.334
23	Pounds of water per square foot, by a mean of several observations	1.240	1.329
24	Water evaporated by one of coal, from initial temperature (a) final result	7.199	7.516
25	Water evaporated by one of coal, from initial temperature (b) during steady action	7.323	6.253
26	Pounds of fuel evaporating one cubic foot of water	8.6818	8.3156
27	Mean temperature of air entering below ash pit, during steady pressure	75°.18	78°.06
28	Mean temp. of wet bulb thermometer, during steady pressure	63°.82	63°.62
29	Mean temperature of air, on arriving at the grate	261°.21	257°.41
30	Mean temperature of gases, when arriving at the chimney	256°.37	320°.65
31	Mean temperature of steam in the boiler	229°.58	230°.65
32	Mean temperature of attached thermometer	73°.0	76°.0
33	Mean height of barometer, in inches	29.814	29.919
34	Mean number of volumes of air in manometer	8.955	8.865
35	Mean height of mercury in manometer in atmospheres	0.164	0.173
36	Mean height of water in syphon draught gauge, in inches	0.202	0.2275
37	Mean temperature of dew point, by calculation	57°.49	55°.19
38	Mean gain of temperature by the air, before reaching grate	186°.03	179°.35
39	Mean difference between steam and escaping gases	31°.26	93°.58
40	Water to one of coal, corrected for temp. of water in cistern	7.1849	7.4953
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	8.1893	8.5068
42	Pounds of water, from 212°, to one cubic foot of coal	442.99	454.30
43	Water, from 212°, to one pound of combustible matter of the fuel	9.603	9.91
44	Mean pressure, in atmospheres, above a vacuum	1.4065	1.4353
45	Mean pressure, in pounds per square inch, above atmosphere	6.004	6.4296
46	Condition of the air plates at the furnace bridge	Open.	Open.
47	Inches opening of damper, (U. upper, L. lower)	U. 6	U. 12

CXXXII, CXXXIII, CXXXIV, CXXXV, CXXXVI.

Midlothian (*average*) *coal.*

3d Trial. (Tab. CXXXIV.)	4th Trial. (Tab. CXXXV.)	5th Trial. (Tab. CXXXVI.)	Averages.	Remarks.
May 25.	*May* 26.	*May* 27.		
24.333	24.417	24.0817		
8.00	6.00	4.50		
12.1875	15.4375	15.4375		
287.0	287.0	377.5		
16.237	20.568	20.568		
10.0	8.0	8 0		
1073.5	886.0	860.25		
1070.87	875.13	850.88		
2.63	10.87	9.37	6.442	
53.675	55.375	53.765	54.0324	
92.72	91.75	119.61	90.268	
7.608	5.943	7.748	6.6762	
14.813	14.753	15.671	14.827	
10.2485	8.4913	8.6663	8.8209	
69.186	57.555	55.303	59.5356	
7825.0	6500.0	6302.0		
71°.0	72°.1	76°.3		
252.0	340.0	932.0		
34.0	45.0	123.0		
650.0	747.5	760.0	630.714	
10.4	11.96	12.16	10.0914	
2.838	2.604	2.013	2.0186	
2.819	2.604	2.024		
7.276	7.3762	7.261	7.3256	
7.010	8.147	8.750	7.4966	
9.7034	8.4732	8.6076	8.7653	
71°.26	77°.50	77°.15		
58°.56	64°.64	66°.08		
252°.81	244°.5	222°.7	247°.726	
448°.09	439°.86	290°.0	289°.007	The gas escaped into the chimney at 320°.6 when combustion was carried on by the upper damper, and at 448° when through the lower; the air plate being *open*, in both cases.
231°.14	230°.64	228°.83		
69°.0	75°.0	75°.0		
29.965	29.981	29.910		
8.740	8.724	8.411		
0.1848	0.1865	0.2166		
0.2034	0.20	0.2371	0.214	
48°.74	57°.64	60°.48		
181°.55	167°.0	145°.55	171°.896	
225°.94	219°.0	70°.37	65°.07	The 3d and 4th trials are omitted in this average.
7.2583	7.3395	7.2383	7.3033	
8.2519	8.3364	8.1919	8.2953	
442.92	461.63	440.44	448.456	
9.6868	9.7791	9.7246	9.7407	The lower damper being drawn, and the gases allowed to escape at 448°, the evaporative effect is diminished 2.2 per cent., as perceived on comparing the result of the 3d with that of the 2d trial.
1.4486	1.4666	1.4234	1.436	
6.6245	6.8916	6.2533	6.4406	
Open.	Closed.	Closed.		
L. 12.	L. 12	U. 12.		

Remarks on the preceding table of deductions.

The third and fourth trials were made with the lower damper open 12 inches; and the former with air plate open, the latter with it shut. With the former arrangement, the gases reached the chimney at an average temperature of 448°, and with the latter at 439°. The higher temperature was accompanied by a range of the syphon gauge slightly superior to what prevailed during the trial with lower temperature. The pound of combustible matter produced more steam with the closed than with the open air plate; and the evaporation with the closed plate also exceeded that with it open, in the proportion of 11.96 to 10.4, as proved in line 21.

For the whole time of burning this coal, the chimney was but 41 feet in height, and the comparison of its average rate of evaporating ought to be made with that of other coals burned under similar circumstances. The average of the five trials is 10.09 cubic feet per hour; that of Karthaus was 12.48; that of Cambria county, Pennsylvania, 12.46. Both the latter coals were in the *average* state as to size of lumps. It appears that the total waste of this average Midlothian coal, in ashes and clinker from the grate, was 14.827 per cent. By table CXVI, it appears that the Midlothian coal from the 900 feet shaft left, on an average, 10.702 per cent. of similar waste. In a subsequent table, (CXLVII,) it will appear that the screened coal from the same company's mine, called *new shaft*, left 10.258; and by table CLIII, the Midlothian "*screened*" coal will be seen to have afforded 10.34 per cent. of waste. All these latter samples appear to have been mined with care, or at least properly separated from slate and dirt; and their very near conformity with each other indicates that a reliance can be placed on this coal, when thus mined and prepared for market, to afford about 89.5 per cent. of its weight in combustible matter. This coal was found to pass in considerable quantities through the grate, requiring much attention to avoid excessive waste.

Where it is stated in the tables of experiments that the contents of the ash pit were *thrown on the grate*, (as generally happens near the foot of the column of "remarks,") it is not to be understood that all which had passed the grate during the day had remained in the ash pit till that time; on the contrary, the contents of the ash pit were frequently returned to the grate throughout the day. The operation generally noted was that which marked the final disposition of the fuel for the closing of the experiment.

This mode of disposing of the contents of the ash pit makes the results in regard both to evaporative power, and to proportion of *waste*, considerably more favorable to every sample than they could be expected to appear according to the usual mode of conducting combustion. The tendency of the coal or its coke to pass through the grate is generally noted, and its liability to loss from this cause may be inferred. In practice on board of steamers, something might, no doubt, be saved by a judicious application of the fallen portions of fuel, which I believe are now generally condemned to go overboard with the cinders. It has been stated that instances have occurred in which nearly 50 per cent. as much weight of matter was thrown out from the ash pit as had been taken on board in the state of coal. If any approach to such a result were really obtained, it argues either the use of a coal far inferior to any which has come under notice in these experiments, or an exceedingly injudicious and wasteful mode of applying it. Instances will be found, in different parts of this series of trials, in which the liability of bituminous coals to fall into fine coke increases this liability to waste beyond what is due to the finer parts of the coal.

No. 8.

Bituminous coal from the Tippecanoe pits, near Petersburg, Virginia.

The following letter accompanied this sample:

"PETERSBURG, *June* 17, 1843.

"SIRS: Herewith we enclose your bill of lading for six hogsheads bituminous coal, from the Tippecanoe pits, and certificate; which, if deficient in form, or otherwise objectionable, you will please let us know, that we may remedy the deficiency.

"The coal sent was taken from the pits this month, and can be delivered either in Boston, New York, Baltimore, Norfolk, or Charleston; though Norfolk would be the most convenient point of delivery.

"Respectfully, your obedient servants,

"J. C. & J. D. OSBORNE & CO.,

"*Agents Tippecanoe Coal Company.*"

In many respects, this sample resembles that from the Clover Hill mines, which has already been described. It parts, however, more readily along the surfaces of deposition, being evidently aided by the great quantity of efflorescent sulphate of iron, which shows itself in those seams. The inclinations of the main partings to those surfaces, in several specimens, were measured, and found to be 83 and 97 degrees. Specimens kept dry for 18 months are already disintegrating. Yellow sulphuret of iron is abundantly distributed over some surfaces of recent fractures. When received, and when placed on the grate, this sample was almost wholly in lumps of considerable size; one or two charges only of fine coal were taken from each hogshead. This will, in part, explain the difference between its weight per cubic foot, as ascertained by actual weighing, and that of several samples of "average" coal from the Virginia coal district.

The powder of this coal is of nearly as light a brown as that of cannel coal, and approaches that of asphalt; its streak is also brown.

The specific gravity of one specimen (*a*) was 1.235; that of another (*b*) 1.4225. The former giving for the weight of a cubic foot 79.37, and the latter 88.91 pounds; of which the mean is 84.14. This very considerable difference in specific gravity was doubtless due to the much greater quantity of earthy matter in *b* than in *a*; but the mean weight per cubic foot may probably not differ far from the actual mean weight of solid coal in the mine, since the average amount of earthy matter, determined in the furnace operations, is not far from the mean amount of the two specimens.

By an average of fifty-five trials in the charge box, the weight per cubic foot (mostly in the state of lumps) was found to be 45.1 pounds, or 0.536 of the above calculated weight. This shows that 49.668 cubic feet of space will be required to stow one ton. The greatest difference between any two charges was found during the first day's trial; in which, the *least* weight per cubic foot was 41, and the *greatest* 52.75 pounds.

The moisture in specimen *a* was 1.235 per cent., and that in *b* 1.395. The drying of 28 pounds in the steaming apparatus for four days occasioned a loss of 1.841 per cent.

The sulphur found in *a* was 0.3775 per cent. The volatile matter, other than moisture and sulphur, in *a*, was, by slow coking, 29.218; and by

rapid coking, 33.378 per cent. By a mean of two trials on *b*, it gave, besides moisture, 32.39 per cent. of volatile matter.

Four incinerations of *a* yielded an average of 2.92 per cent., and eight of *b* gave 14.804 per cent. of ashes.

These two specimens may, therefore, be stated to consist of the following proximate ingredients, viz :

	Specimen *a*.	Specimen *b*.
Moisture - - - - -	1.235	1.395
Sulphur - - - - -	0.377	(not tried.)
Volatile combustible, by rapid coking -	33.378	32.390
Earthy matter - - - - -	2.920	14.804
Fixed carbon - - - -	62.090	51.411
	100.	100.
Volatile to fixed combustible -	1 : 1.860	1 : 1.586

Two specimens examined by Dr. King gave the mean amount of volatile matter, including moisture, 37.625 per cent.; and this, combined with the mean of the two above presented, viz : 34.387, gives as the average of four specimens 36.006.

During the experiments on evaporation, there were consumed, at five trials, 4,904.75 pounds of coal ; and this afforded of *ashes*, including those of wood, 279.125 pounds, weighing 57.44 pounds per cubic foot ; of clinker, 200.5 pounds, weighing 43.37 pounds per cubic foot ; and 44 pounds of soot, weighing only 5.54 pounds per cubic foot.

The ashes lost by reincineration 8.48, the clinker 3.915, and the soot 64.74 per cent. of weight. By reducing the above numbers in these proportions, we have—

Of absolutely incombustible matter in the ashes -	- 255.45	pounds.
clinker	- 192.65	"
soot -	- 15.51	"
	463.61	"
From which deduct ashes of 1,246.25 pounds of wood =	3.826	"
And we have of incombustible matter of the *coal* alone	459.784	"

Which is 9.374 per cent. of the coal consumed.

Hence it appears that the mean proportion of earthy matter of the two specimens above analyzed, viz : $\frac{2.92+14.804}{2}$ =8.862 per cent., is 0.512 less than the average of that of the whole sample.

From these determinations on the large scale, we have the composition of the coal as follows :

Moisture, by drying 28 pounds - -	1.841	per cent.
Other volatile matter, mean from 4 specimens -	34.165	"
Earthy matter, from 4,904.75 pounds - -	9.374	"
Fixed carbon, computed by difference - -	54.620	"
	100.	

The volatile is to the fixed combustible as 1 : 1.5987

The clinker of this coal is, in all respects, similar to that of the Clover Hill sample. By reference to a tabular comparison of residua, in a subsequent part of this report, (table CXC,) it will be seen that while the last-mentioned coal gave 3.86 per cent. of its weight in clinker, the Tippecanoe gave 4.03—a difference which may easily have arisen from differences in the rates of combustion, which in the latter was 108 pounds, and in the former only 90 pounds per hour. The gauge which indicated the draught in the chimney will be seen, on inspecting the table of deductions, to have marked a difference corresponding to this difference of rates; and the intensity of ignition, being in some degree proportionate to the rate of combustion, will account for a larger amount of clinker in one case than in another. The final residue of the clinker, after calcination, is of a bright red color; that from reincinerating the ashes is slightly lighter; that from the soot still a shade lighter; and the ashes from analysis vary from an ochrey yellow to a bright red.

Treated with oxide of lead, 20 grains of the above-described specimen (*a*) yielded 559.16 grains, or 27.958 times its weight of metallic lead; and this, after deducting moisture and earthy matter, is 29.17 to 1 of combustible matter of the specimen.

The soot contained 13.904 per cent. of volatile matter, and 50.84 of fixed carbon.

In the smith's fire this coal was found well suited for the small work in hand at the time it was tried. It produced but a moderate quantity of cinder. The coke becomes very hard, which was judged to favor the formation and continuance of a large hollow fire. It heats well, without apparently injuring the iron.

In the chain shop, where it was used in making the links of a small chain, the workman complained that the welding was sometimes interfered with by the sulphur of the coal. The coke appeared not inclined to agglutinate strongly; but in that case, as a hollow fire was not required, no attempt was made to produce one. The hardness of the coke was rather objectionable than otherwise.

In an office grate, it was found to give a brisk, highly luminous flame, resembling that of the Midlothian coal.

For the manufacture of illuminating gas, it is perhaps equal to any other Virginia coal. The amount of its volatile ingredients is greater than that of Nova Scotia coals. Its distillation will, no doubt, give rise to a considerable quantity of ammoniacal liquor, and probably of carbonic acid, from the earthy carbonates distributed through the seams. Sulphuretted hydrogen will also be found among its gaseous products.

It could not be employed in the smelting of iron from the ore, without previous coking.

In the furnace of the steam boiler, it was observed to ignite promptly, burn freely, with a large dense red flame, and to agglutinate while coking, so as to allow but a moderate quantity to pass through the grate.

The average time required by this coal to bring the boiler into steady action was 1.333 hour; and the weight of coke left unburnt, after the fire had become extinct, was 11.25 pounds. In this last circumstance, it corresponds very nearly with the Creek Company's coal, the Clover Hill, and the Chesterfield Mining Company's samples.

TABLE CXXXVIII.—

First trial—upper damper 12

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back				Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
May 9	5 45	60	–	120	120	67	134	–	30.02	–	–	–	–	–
	8.00	[illegible]	–	165	190	67	[illegible]	–	30.07	–	–	0.13	–	–
	8.40	60.5	–	200	206	67	226	–	30.08	0.169	9.00	0.13	–	–
	8.45	60.5	–	202	208	67	227	–	30.08	0.180	8.78	0.15	–	84.50
	9.25	61	–	212	224	67	230	–	30.09	0.183	8.76	0 18	235	88.00
	10.25	62	–	280	234	66	230	–	30.09	0.180	8.79	0.18	825	84.50 / 88.25
	11.00	[illegible]	–	350	234	66	230	–	[illegible]	0.179	[illegible]	0.18	1000	[illegible]
	11.40	63	–	[illegible]	244	66	[illegible]	–	30.07	0.177	8.82	0.18	1420	93.00
	P. M.													
	0.40	63	–	–	246	67	230	–	30.08	0.180	8.79	0.20	1890	88.50
	1.40	64	–	428	266	66	230	–	[illegible]	0.177	8.82	0.20	2450	95.75
	2.40	[illegible]	–	470	256	67	[illegible]	–	30.07	0.180	8.78	[illegible]	2710	95.00
	3.20	[illegible]	–	480	254	67	231	–	30.06	0.179	8.80	[illegible]	3190	105.50
	4.00	63	–	480	254	67	230	–	30.06	0.179	8.80	0.19	3270	–
	4.50	62.5	–	510	244	67	230	–	30.07	0.179	[illegible]	0.19	3685	87.75
	5.10	62	–	520	242	68	230	–	[illegible]	0.174	8.85	[illegible]	3940	–
	6.00	62	–	530	240	65	230	–	30 08	0.172	[illegible]	0.19	4140	[illegible]
	A. M.													
May 10	5.45	56	–	–	204	65	222	–	30.14	0.091	[illegible]	0.18	4480	–
	6.30	56	–	250	192	65	[illegible]	–	30.14	–	–	0.18	6270	–

Period of steady action, from 9*h*. 50*m*. a. m. to 6*h*. p. m.=8*h*. 10*m*. Coal supplied to the grate, 818 lbs.; water to the boiler, 3,894 lbs., water to 1 of coal, 4.760.

TIPPECANOE COAL.

inches open; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet, length of circuit of heated gases 121 feet; height of chimney 41 feet.
					Before commencing this trial, the flues had all been thoroughly swept, and the boiler emptied, cleansed, and refilled.
h. m.					
-	-	60	—14	-	Commenced firing; both dampers open; water 0.3 inch below normal level.
-	-	165	—10	-	Water at normal level.
-	-	139.5	—20	-	Wood consumed, 387 lbs.; steam at equilibrium; commenced charging with coal; lower damper closed; upper set at 16 inches; steam blows off at 8*h*. 45*m*. a. m.
8.45	-	141.5	—19		
9.00	-	151	— 6	0.934	
9.50 ... 10.25	-	218	+ 4	1.563	
11.00	-	288	4	0.795	
11.40	-	327	14	1.934	Much smoke from chimney.
0.40	-	-	16	1.245	
1.40	-	364	36	1.483	
2.40	-	466	25.5	0.689	
3.45	-	416	23	1.907	
-	-	417	24	0.318	Smoke 40 seconds in reaching chimney top.
4.50	-	447.5	14	1.319	Placed 28 lbs. of this coal in drying apparatus.
-	-	458	12	2.026	Filled tank at 5*h*. 30*m*. p. m.
6.00	-	468	10	0.636	Contents of ash pit thrown on grate.
-	-	-	—18	-	Some fire on grate this morning.
-	-	194	—14	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	46.75
Ashes - - - - - - - - - -	53.50
Ashes behind bridge - - - - - - - -	10.25
Total clinker and ashes - - - - - - - -	110.50
Deduct wood ashes - - - - - - - -	0.119
Total waste from coal - - - - - - - -	110.381
Coke - - - - - - - - - -	7.25

TABLE CXXXIX.—

Second trial—upper damper 6

Date.	Hour.	TEMPERATURES OF THE: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
May 10	6.30	56	–	250	192	65	206	–	30.14	–	–	0.18	–	–
	8.25	56	–	250	234	65	226	–	30.14	0.169	9.00	0.18	–	82.00
	8.40	56	–	255	236	65	227	–	30.14	0.176	8.82	0.18	–	–
	9.15	56	–	–	280	65	229	–	30.14	0.190	8.69	0.20	330	82.00
	10.05	56	–	–	298	65	230	–	30.14	0.193	8.66	0.20	670	83.75
	10.40	56	–	280	282	65	230	–	30.15	0.193	8.66	0.20	910	–
	11.00	56.5	–	320	292	65	230	–	30.16	0.193	8.66	0.20	1240	86.50
	11.30	57	–	350	302	65	230	–	30.15	0.194	8.65	0.20	1410	–
	11.50	57	–	360	302	65	231	–	30.14	0.195	8.64	0.20	1660	85.75
	P. M.													
	0.30	56.5	–	380	314	62	230	–	30.12	0.195	8.64	0.22	2065	–
	1.30	56	–	395	314	62	230	–	30.15	0.191	8.68	0.22	2645	91.50
	2.10	56	–	400	322	62	230	–	30.13	0.189	8.70	0.22	3150	90.00
	2.50	55.5	–	400	328	62	230	–	30.13	0.195	8.64	0.22	3490	86.50
	3.30	55.5	–	400	320	62	230	–	30.13	0.197	8.62	0.21	3730	–
	4.10	54	–	410	318	63	230	–	30.12	0.193	8.66	0.22	4315	103.50
	5.00	55	–	415	312	62	230	–	30.12	0.190	8.69	0.21	4750	92.75
	5.25	55	–	410	310	62	230	–	30.12	0.193	8.66	0.22	4985	–
	6.00	55	–	420	310	61	230	–	30.12	0.190	8.70	0.20	5365	86.25
	A. M.													
May 11	6.20	52.5	–	210	188	60	219	–	30.15	0.073	9.86	0.10	–	–
	7.00	52.5	–	–	–	60	204	–	30.15	–	–	–	7020	–

Period of steady action, from 10*h*. 5*m*. a. m. to 6*h*. p. m.=7*h*. 55*m*.; coal supplied to the furnace, 722.75 lbs.; water to boiler, 4,695 lbs.; water to 1 of coal, 6.496.

TIPPECANOE COAL.

inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.			
h. m.					
-	-	194	—14	-	Commenced firing; water at normal level.
8.25	-	194	+ 8	-	Wood consumed, 163¼ lbs.; commenced charging with coal.
-	-	199	9	-	Steam begins to blow off; upper damper set at 16 inches.
9.10	-	-	51	1 499	Damper reduced to 12 inches.
10.05	-	-	68	1.061	
-	-	224	52	1.089	Damper reduced to 8 inches.
11.00	-	263.5	62	2.622	
-	-	293	72	[illegible]	
[illegible]	-	303	71	1.987	Filled tank at m.
-	-	323.5	84	[illegible]	Damper reduced to 6 inches.
0.45	-	339	84	1.536	
1.30	-	344	92	2.007	
2.50	-	[illegible]	98	1.351	Smoke 29 seconds in reaching chimney top,
-	-	344.5	90	0.953	
4.10	-	356	88	2.324	This coal is almost entirely in lumps.
5.00	-	360	82	1.383	Not much smoke from chimney to-day; raining nearly all day.
-	-	[illegible]	[illegible]	1.494	Filled tank at 5*h*. 40*m*. p. m.
6.00	-	365	80	1.726	Contents of ash pit thrown on grate.
-	-	157.5	—31		
-	-	-	-	+	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	29.75
Ashes	57.50
Ashes behind bridge	9.50
Total clinker and ashes	96.75
Deduct wood ashes	0.50
Total waste from coal	96.25
Coke	23.00

TABLE CXL.—TIP

Third trial—upper damper 8

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
May 12	5.50	57.5	–	–	156	59	204	–	30.03	–	–	0.09	–	–
	7.45	59	–	–	242	58	227	–	30.06	0.159	9.00	0.20	–	–
	8.05	59.5	–	130	252	58	227	–	30.06	0.171	8.87	0.20	–	91.50
	8.45	62	–	145	306	59	229	–	30.06	0.185	8.74	0.20	80	[illegible]
	9.30	64.5	–	160	344	60	229	–	[illegible]	0.185	8.74	0.18	570	69.50
	10.15	68	–	200	338	60	230	–	30 06	0.181	8.78	0.18	1150	82.75
	10.55	69	–	260	314	61	230	–	30.06	0.183	8.76	0.19	1460	89.25
	11.25	69	–	280	340	61	230	–	30.06	0.185	8.74	0.19	1790	93.00
	P. M.													
	0.00	69	–	310	350	62	231	–	30.06	0.183	8.76	0.20	1875	–
	0.45	69	–	350	342	62	231	–	30.04	–	–	0.19	[illegible]	102.75
	1.40	70	–	360	330	62	231	–	30.03	0.179	[illegible]	[illegible]	3435	85.25
	2.25	70	–	390	338	62	[illegible]	–	[illegible]	0.177	8 82	0.19	3690	85.50
	3.20	71.5	–	430	312	63	230	–	30.01	0.172	[illegible]	0.18	4380	96.75
	4.15	72	–	460	322	63	231	–	30.06	0.169	8.90	0.18	[illegible]	89.00
	5.00	73	–	480	314	64	231	–	30.00	0.169	[illegible]	0.18	5295	96.25
	5.30	73	–	[illegible]	[illegible]	64	230	–	30.00	0.169	[illegible]	0.17	5515	–
	6.00	73	–	520	304	62	230	–	29.98	0.165	8.94	0.15	5680	90.25
	A. M.													
May 13	5.40	60	–	230	210	64	220	–	29.99	0.076	9.83	0.10	[illegible]	–
	6.30	62	–	210	190	64	206	–	29.99	–	–	0.10	7755	–

Period of steady action, from 9*h.* 30*m.* a. m. to 6*h.* 0*m.* p. m.=8*h.* 30*m.*; coal supplied to the grate, 910.75 lbs.; water supplied to boiler, 5,110 lbs.; water to 1 of coal for this period, 5.61.

PECANOE COAL.

inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.113 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
					Interior flues of boiler swept bef[illegible] commencing this experiment.
h. m.					
-	-	-	—48	-	Commenced firing; water at normal level.
-	-	-	+15	-	Wood consumed, 147¼ lbs.; steam at equilibrium; commenced charging with coal.
8.05	-	70.5	25	-	Steam blows off; air plates opened; damper set at 16 inches.
8.45	-	83	77	0.318	
9.30	-	115.5	115	1.731	
10.15	-	132	108	2.031	Damper reduced to 12 inches.
10.55	-	191	84	1.311	
11.25	-	211	110	1.642	
-	-	241	119	0.386	Filled tank; damper reduced to 10 inches.
0.40	-	281	111	3.143	Damper reduced to 8 inches.
1.40	-	290	99	1.936	
2.25	-	320	108	0.901	
3.20	-	358.5	82	1.994	
4.15	-	388	91	1.457	Smoke 25 seconds in reaching chimney top.
5.00	-	407	83	1.448	The coal consumed to-day generally in lumps.
-	-	417	80	1.166	Filled tank at 5*h*. 45*m*.
6.00	-	447	74	0.874	
-	-	170	—10	-	Some fire remaining on grate.
-	-	148	—16	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	45.25
Clinker behind bridge - - - - - - - -	0.81
Ashes - - - - - - - - - - -	51.50
Ashes behind bridge - - - - - - - -	3.991
Total clinker and ashes - - - - - - - -	101.551
Deduct wood ashes - - - - - - - - -	0.453
Total waste of coal - - - - - - - - -	101.098
Coke - - - - - - - - - - -	12.27

TABLE CXLI.—TIP

Fourth trial—upper damper 8

Period of steady action, from 10*h*. a. m. to 6*h*. p. m.; coal supplied to the grate, 731 lbs.; water to boiler, 4,720 lbs.; water to 1 of coal, 6.457.

PECANOE COAL.

inches open; air plates open.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.113 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					Interior flues of boiler swept before commencing this experiment.
-	-	148	—16	-	Commenced firing; water at normal level.
-	-	136	—65	-	Wood consumed, 142¼ lbs.; commenced charging with coal; steam at equilibrium.
8.15	-	141	—29	-	Upper damper set to 16 inches at 8*h*.; steam blows off at 8*h*. 15*m*. a. m.
9.15	-	159	+12	1.073	Damper reduced to 12 inches; thermometer, which measures temperature of air arriving at the grate, is broken; observations on that subject are necessarily omitted for the rest of the day.
10.00	-	-	114	1.801	Damper 9 inches; smoke 27 seconds in reaching chimney top.
10.50	-	-	120	1.812	Damper at 8 inches.
-	-	-	120	1.081	Smoke 27 seconds in reaching chimney top; filled tank at 11*h*. 30*m*. a. m.
11.50	-	-	108	1.862	
0.40	-	-	114	1.589	
1.35	-	-	101	2.167	Smoke 27 seconds in reaching chimney top.
-	-	-	106	1.219	
2.45	-	-	100	2.225	
-	-	-	90	1.158	
4.00	-	-	95	1.689	Except the fourth charge, the coal consumed in this experiment was generally in lumps.
-	-	-	100	1.291	
5.00	-	-	102	2.066	Coal in drying apparatus weighs 27 lbs. 7¾ oz.
-	-	-	101	0.863	Filled tank at 5*h*. 50*m*. a. m.
6.00	-	-	94	1.081	Contents of ash pit thrown on grate.
-	-	-	— 1	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	49.69
Ashes	46.25
Ashes from behind bridge	3.384
Total clinker and ashes	99.324
Deduct wood ashes	0.436
Total waste from coal	98.888
Coke	7.228
Soot	40.75

TABLE CXLII.—TIP

Fifth trial—upper damper 8 inches open; air plates open

Period of steady action, from 9*h*. 15*m*. a. m. to 0*h*. 19*m*. p. m. =3*h*. 4*m*.; coal supplied to the furnace, 744.5 lbs.; water to the boiler for the same time, 8,240.3 lbs.; water to 1 of coal, 6.829.

PECANOE COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature of the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h m.					
-	-	50	-	-	Commenced firing at 5*h.* 27*m.*; water then 0.98 inch below normal level.
-	-	59	+50		
8.12	-	70	7	-	Wood consumed, 406 lbs.; commenced charging with coal; steam blows off at 8*h.* 18*m.*
8.40	-	72	24	2.778	Air plates opened at 8*h.* 40*m.*
9.15	18.1	81	72	1.631	Steam allowed to escape from back valve; damper reduced to 8 inches.
-	27.6	98	81	2.204	
9.50	26.2	114	81	3.995	
10.22	27.9	133	79	2.702	
11.00	29.7	148	89	1.871	Filled tank at 11*h.* 50*m.*; commenced drawing gases at 11*h* 38*m.*; drew in 36 minutes 100 cubic inches, which gave water 1.06 grain, carbonic acid 6.04 grains, and oxygen 8.75 cubic inches; temperature of bath 44°.
11.35	29.7	160	88	3.614	
0.19	29.5	173	84	2.381	
-	33.3	184	101	3.195	Air plates closed, and contents of ash pit thrown on grate.
-	29.5	192	58	1.166	
-	26.4	192.5	64	0.413	Reduced damper to 4 inches.
-	25.3	192	29	0.863	Filled tank.
-	25.3	186	16		
-	23.0	177	— 4	0.230	Adjusted water to the proper level; double weighted the safety valves, but the pressure does not rise. Experiment concluded.

RESIDUA.

	Pounds.
Clinker	28.25
Ashes	40.00
Ashes behind bridge	3.25
	71.50
Deduct wood ashes	1.246
Total waste from coal	70.254
Coke	7.50
Soot	3.25

TABLE CXLIII.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (T. CXXXVIII.)	2d Trial. (T. CXXXIX.)
		May 9.	*May* 10.
1	Total duration of the experiment, in hours	24.75	23.833
2	Duration of steady action, in hours	8.166	7.916
3	Area of grate, in square feet	16.25	16.25
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.65	21.65
6	Number of charges of coal supplied to grate	12.0	11.0
7	Total weight of coal supplied to grate, in pounds	1075.0	970.5
8	Pounds of coal actually consumed	1067.75	948.5
9	Pounds of coal withdrawn and separated after trial	7.25	22.0
10	Mean weight, in pounds, of one cubic foot of coal	44.791	44.113
11	Pounds of coal supplied per hour, during steady action	100.171	91.302
12	Pounds of coal per square foot of grate surface, per hour	6.164	5.618
13	Total waste, ashes and clinker, from 100 pounds of coal	10.237	10.147
14	Pounds of clinker alone, from 100 pounds of coal	4.3315	3.1207
15	Ratio of clinker to the total waste, per cent.	41.855	30.753
16	Total pounds of water supplied to the boiler	6370.0	7020.0
17	Mean temperature of water, in degrees Fahrenheit	66°.2	62°.1
18	Pounds of water supplied at the end of experiment, to restore level	1790.0	1275.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	251.0	183.0
20	Pounds of water evaporated per hour, during steady action	476.8	593.1
21	Cubic feet of water per hour, during steady action	7.628	9.489
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.263	1.571
23	Pounds of water per square foot, by a mean of several observations	1.265	1.614
24	Water evaporated by 1 of coal, from initial temperature (a) final result	5.637	7.208
25	Water evaporated by 1 of coal, from initial temperature (b) during steady action	4.7604	6.496
26	Pounds of fuel evaporating one cubic foot of water	11.087	8.6709
27	Mean temperature of air entering below ash pit, during steady pressure	62°.71	55°.8
28	Mean temp. of wet bulb thermom., during steady pressure	–	–
29	Mean temperature of air, on arriving at the grate	387°.5	380°.0
30	Mean temperature of gases, when arriving at the chimney	244°.83	306°.93
31	Mean temperature of steam in the boiler	230°.12	230°.0
32	Mean temperature of attached thermometer	60°.0	53°.0
33	Mean height of barometer, in inches	30.075	30.128
34	Mean number of volumes of air in manometer	8.807	8.663
35	Mean height of mercury in manometer, in atmospheres	0.1785	0.193
36	Mean height of water in syphon draught gauge, in inches	0.1909	0.2107
37	Mean temperature of dew point, by calculation	–	–
38	Mean gain of temperature by the air, before reaching grate	324°.79	324°.2
39	Mean difference between steam and escaping gases	14°.71	76°.93
40	Water to 1 of coal, corrected for temp. of water in cistern	5.654	7.208
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	6.4543	8.2577
42	Pounds of water, from 212°, to 1 cubic foot of coal	289.09	364.27
43	Water, from 212°, to 1 pound of combustible matter of the fuel	7.1904	9.1902
44	Mean pressure, in atmospheres, above a vacuum	1.4107	1.4287
45	Mean pressure, in pounds per square inch, above atmosphere	6.0652	6.3315
46	Condition of the air plates at the furnace bridge	Removed.	Removed.
47	Inches opening of damper, (U. upper)	U. 12	U. 6

TABLES CXXXVIII, CXXXIX, CXL, CXLI, CXLII.

Tippecanoe coal.

3d Trial. (Table CXL.)	4th Trial. (Table CXLI.)	5th Trial. (Table CXLII.)	Averages.	Remarks.
May 12.	*May* 13.	*Nov.* 14.		
24.66	25.5	10.25		
8.5	8.0	3.066		
14.113	14.113	14.07		
377.5	377.5	377.5		
18.79	18.79	18.75		
13.0	11.0	8.1		
1177.75	992.25	745.5		
1165.48	985.02	738.0		
12.27	7.23	7.5	11.25	
45.298	45.102	45.987	45.058	
107 147	91.375	154.762	108.951	
7.592	6.474	10.999	7.3694	
8.674	10.039	9.5195	9.7233	
3.934	5.0232	3.7602	4.0339	
45.351	50.036	39.50	41.499	
7756.0	7320.0	5317.0		
61°.9	64°.2	40°.7		
1675.0	1685.0	0.0	–	The fifth trial needed no water to be added to restore level at the end of the experiment, which was begun and concluded on the same day.
236.0	231.0	0.0		
601.176	590.0	1056.859	663.587	
9.618	9.44	16.937	10.6224	
1.5925	1.562	2.799	1.7575	
1.524	1.546	2.795		
6.4514	7.1968	7.2046	6.7395	
5.61	6.457	6.829	6.0305	
9.6678	8.6844	8.6715	9.3609	
69°.71	72°.67	46°.14		
–	–	48°.36		
349°.79	–	186°.72	325°.25	
326°.0	328°.47	304°.55	302°.15	
230°.21	230°.0	229°.91		
67°.0	70°.0	42°.73		
30.031	29.959	30.321		
8.82	8.856	4.896	–	The fifth trial, it will be observed, was made at a time when the bulk of air in the manometer had undergone the last diminution to which it was subjected during the experiments.
0.177	0.174	0.569		
0.1833	0.1846	0.3966	0.2312	
–	–	27°.79		
277°.68	–	140°.58	266°.66	
95°.79	98°.47	74°.64	72°.11	
6.4514	7.1968	7.2046	6.7429	
7.391	8.2309	8.4085	7.7485	In its variableness of efficiency at the different trials, as well as in many other circumstances, this coal bears a striking resemblance to that of Clover Hill.
334.79	371.23	391.78	350.23	
8.0929	9.1494	9.2932	8.5832	If the first trial be excluded, the average of the rest will be 8.9314.
1.4242	1.4232	1.4431	1.426	
6.2653	6.251	6.5447	6.2915	
Open.	Open.	Open.		
U. 8	U. 8	U. 8		

No. 9.

Bituminous screened coal from the mines of the Midlothian Coal Company's "new shaft," Virginia.

For information relative to the origin of this coal, I relied on the markings of the casks which contained it, and which purported that it came from a "*new shaft*" in the company's works, from 700 to 800 feet deep. It was received and used in the lump form, which it retained with considerable force. Its fresh fractures present a shining black resinous, scarcely conchoidal aspect, with distinct lines of the laminæ of deposition. It is mostly free from incrustations of earthy matter, but occasionally presents some shaly or pyritous portions.

The powder is of a light brown, indicating a pretty high degree of bituminousness; and its streak is nearly of the same color.

The specific gravity of two specimens (*a* and *b*) was found to be 1.3495 and 1.3006, respectively; the mean of which affords by calculation the weight of 1 cubic foot of the coal in the solid state=82.43 pounds.

By thirty-one trials in the charge box, the mean weight per cubic foot was ascertained to be 47.899 pounds—the lowest result being 42.75, and the highest 54.125. Hence the actual is to the calculated weight as 0.5811 to 1.

The space required for the stowage of one gross ton is 46.769 cubic feet.

In the analysis of specimen *a*, the moisture was found to be 0.74 per cent., and that of *b* 0.914 per cent. In the steam drying apparatus, 28 pounds lost in three days only 3 ounces, or 0.6696 per cent.

The sulphur in *b* was 2.282 per cent.

Of volatile matter, other than moisture, *a* had 34.72, and *b* 31.556 per cent.

The coking took place with the emission of a beautiful bright flame. This indicated a large proportion of olefiant gas, and the absence of carbonic acid, or other incombustible gaseous matter. Two specimens tried by Dr. King gave a mean of 35.75 per cent. of volatile matter, including moisture.

The incineration of *a* produced 9.549, and that of *b* 5.48 per cent. of the raw coal. Hence, the composition of the two may be thus represented:

	Specimen *a*.	Specimen *b*.
Moisture - - - -	0.740	0.914
Sulphur - - - -	(not tried.)	2.282
Volatile combustible - - -	34.720	29.274
Earthy matter - - - -	9.549	5.480
Fixed carbon - - - -	54.991	62.050
	100.	100.
Volatile to fixed combustible -	1 : 1.584	1 : 1.966

The quantity of coal burned during the three trials of evaporative effect was 2,918.5 pounds.

The waste matter withdrawn consisted of—

Ashes, including 1.932 pound of wood ashes -	175.25 pounds.
Clinker - - - - - -	126.25 "
Soot - - - - - - -	14.00 "
The *ashes* lost by reincineration - -	16.18 per cent.
The *clinker* - - - - - -	0.00 "
The *soot* - - - - - -	56.75 "

Reducing the ashes and soot in these proportions, and deducting the wood ashes, we have left 277.4—1.932=275.473 pounds of absolutely incombustible matter, or 9.44 per cent. of the coal consumed. The trials in the large way show this coal to consist of—

Moisture, from 28 pounds - - - -	0.6696
Other volatile matter, from four specimens - -	33.4904
Earthy residuum, from 2,918.5 pounds - -	9.4400
Fixed carbon, by difference - - - -	56.4000
	100.

The volatile is, therefore, to the fixed combustible as 1 : 1.684.

The weight per cubic foot of the

Ashes, was - - - - - -	56.65 pounds.
Clinker - - - - - - -	30.12 "
Soot - - - - - - -	5.46 "

The clinker is brown on the outside; but on the fractured surfaces black, very compact, and heavy; in sheets of considerable extent, manifestly very fusible, and tending to adhere to the grate. The highly ferruginous character which it presents, is in accordance with the large amount of sulphur which was detected in one of the specimens above analyzed.

The shaly portions embraced in the vitrified clinker are nearly obscured by the fusible coating which encloses them.

A portion of the specimen *b*, above analyzed, was subjected to treatment with the oxide of copper: 4.57 grains were thoroughly dried; and the result of their treatment, with all the precautions required by the experiment, was of *water* 2.23, and carbonic acid 14.82 grains.

The *earthy matter* of the raw coal having been determined, as also the moisture, by previous experiments already detailed, it is easy to calculate the weight of earthy matter in 4.57 grains of *dried* coal to be 0.25274 grain, which leaves of combustible matter 4.31726 grains; the hydrogen, by analysis, is 0.24777, the carbon 4.04182 grains; leaving for oxygen and azote only 0.02767, or the relation of these three to their sum is—

Carbon - -	$\frac{4.04182}{4.31726}$ = 93.6200 =	15.60 C.	in atoms.
Hydrogen - -	$\frac{0.24777}{4.31726}$ = 5.7391 =	5.74 H.	"
Oxygen and azote -	$\frac{0.02767}{4.31726}$ = 0.6409 =	0.80 O.	"
	100.		

In the raw coal, this analysis enables me to state that the ingredients are—

Moisture - - - - -	0.914
Carbon - - - - - -	87.634
Hydrogen - - - - -	5.372
Oxygen and azote - - - - -	0.600
Earthy matter - - - - - -	5.480
	100.

That the relative amounts of carbon and hydrogen were correctly determined in the preceding analysis, was rendered highly probable by the result of another trial, in which the apparatus became injured before the combustion was complete; but the ratio of the two products to each other was very nearly the same as in the preceding trial: The carbon was 1.2736 grain, against hydrogen 0.07222 grain. As the sum of the hydrogen and oxygen is 5.972 per cent., and that of sulphur 2.282, it is inferred that, in the volatile matter produced by the distillation of this coal, there will be found 29.274—5.972=23.302 per cent. of its carbon. If the heating power be calculated from the above analysis by the organic method, without taking account of the sulphur, and only deducting of the hydrogen so much as is equivalent to the oxygen present, we have the calorific power expressed by 14,596;* or in pounds of water from 212°, for 1 of coal, 14.171. This is far above the actual result of experiment. The highest evaporative power, even when allowance was made for the heat expended on the products of combustion, as well as for that employed on the steam of the boiler, was but 10.1915. This will be evident from an inspection of the table of analyses of gases from the chimney. (See table CXCIV.)

A trial of specimen *b* by the oxide of lead gave 25.084 times its weight in metallic lead. Deducting earthy matter and moisture, this gives for 1 of combustible matter 26.797.

In both the chain and anchor shops, the action of this coal was entirely satisfactory. It was tried near the end of the season, and was pronounced by the workmen (now accustomed to observe carefully the action of each coal) to be one of the best, both for large and small fires, which they had tried.

The characters already detailed are sufficient to indicate its fitness for domestic purposes. It ignites rapidly, having required, on an average, only 0.906 hour to bring the boiler to steady action. It burns with a long, dense, deep-red flame—agglutinating when first thrown on the grate into

* Thus the carbon is 0.87634 of the coal, (considering all that was collected in the potash tube as carbonic acid;) and this multiplied by 12,906, (Dulong's result for the heating power of carbon,) we have 11,284 for the computed heating power of the carbon in the coal. This divided by 1,030 gives the steam generating power to 1 of coal=10.955. Deducting $\frac{1}{8}$ of 0.600 (the oxygen) from 5.372, we get 5.297; and, multiplying by 62,535, (the heating power of hydrogen,) we obtain 3.312; and the sum of these is 14,596, as above. By deducting the moisture (0.6696 per cent.,) and the *waste* left in the third trial of this coal, (10.397 per cent.,) we have the remainder 88.933 per cent. of combustible matter, by which the total evaporative affect 10.1915 must have been produced. Hence $10.1915 \div 0.88933 = 11.460$ = the evaporative power of the unit of matter actually burned in that experiment. Again: as in the sample analyzed, the *combustible part* is $0.87634 + 0.05372 + 0.00600 = 0.93606$, the *carbon* is $0.87634 \div 0.93606 = 0.9362$ of that combustible; and $0.9362 \times 12906 = 12083$, the *heating power* of the carbon in 1 of this combustible; and, finally, $12083 \div 1030 = 11.731$ = its *evaporative power*.

a rather solid, moderately intumescent mass, requiring some effort to break it up. When thoroughly ignited, it still retains sufficient size to prevent much waste through the grate. The average weight of unburnt coke left on the grate after each trial was 17.083 pounds.

On the subject of the pressures maintained in the course of these experiments, I would remark, that in several instances it became necessary to increase the ordinary weights on the safety valves, to prevent foaming, and especially to equalize the discharge of steam from the two. This was done by small additions placed upon the principal weights, and which were varied from time to time, as the action of the boiler seemed to demand. When a strong west or northwest wind aided the draught, a larger portion of steam was permitted to escape at the back valve, and the front one was loaded. If, on the other hand, the gauge for draught indicated a deficiency, the front valve was relieved, and more steam allowed to pass into the chimney.

In regard to the observations of temperature of steam in the boiler, it was found necessary frequently to attend to the thermometer inserted in it, lest, by the slow evaporation of mercury, which takes place at degrees below the boiling point of that metal, some portions should become lodged in the upper part of the tube. The vapor, being invisible, lodges for a time in so fine globules on the interior of the glass, as not to attract attention. On reversing the instrument, however, and gathering all the dispersed portions, the total length of the column may sometimes be found increased from 1 or 2 to 4 or 5 degrees. In some of the earlier experiments, it will be observed that the temperature of steam in the boiler ranged as low as 229, or even 228 degrees, while the average is from 230 to 231 degrees. It will be seen that, during the trials of this coal, the temperatures and pressures were maintained with tolerable uniformity throughout. This will appear from table CXLVII. The first thermometer had a range rather lower than that which was employed at a later period of the research. The error was from 1½ to 2 degrees.

TABLE CXLIV.—MIDLO

First trial—upper damper 8 inches open ; air plates open ;

	h. m.							Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water in tank.	Weight of coal supplied to grate at each time.
	A. M.													
Sept. 13	5.35	60	57	98	–	66	[illegible]	61	30.17	0.363	6.92	0.02	–	–
	6.15	64	60	122	212	66	226	62	30.19	0.527	[illegible]	0.22	–	92.25
	[illegible]	64	60	128	216	65	226	62	30.19	0.547	5.10	0.23	–	91.25
	9.00	[illegible]	61	140	–	66	229	[illegible]	30.20	0.644	5.13	0.26	471	–
	9.30	68	62	160	272	66	230	64	30.20	0.567	4.91	[illegible]	1053	92.50
	10.00	69	62	175	310	66	230	[illegible]	30.20	0.553	[illegible]	0.40	1463	–
	10.30	71	64	200	290	66	230	66	[illegible]	0.558	[illegible]	0.40	1965	95.50
	11.00	72	65	214	297	[illegible]	230	68	30.19	[illegible]	5.00	0.40	2378	97.00
	11.30	73	65	232	300	64	232	69	30.19	0.558	5.00	0.38	2770	–
	P. M.													
	0.00	73	45	243	306	64	233	69	30.17	0.561	4.97	[illegible]	3288	95.00
	0.30	74	[illegible]	254	312	64	231	69	30.17	0.551	5.06	0.35	3710	–
	1.00	73	66	270	292	64	232	70	30.17	0.546	5.09	0.33	4315	95.50
	1.30	74	66	276	296	64	232	70	30.17	0.551	[illegible]	0.36	4562	108.25
	2.00	73	65	278	[illegible]	[illegible]	232	[illegible]	30.17	0.553	5.04	[illegible]	4984	–
	[illegible]	72	65	282	323	[illegible]	230	69	30.16	0.548	5.10	0.35	5391	92.50
	[illegible]	72	65	292	312	64	232	69	30.16	0.553	5.04	0.36	5893	–
	[illegible]	73	[illegible]	295	322	64	232	[illegible]	30.15	0.552	5.06	0.36	6303	90.00
	4.00	75	65	304	295	64	232	69	30.16	0.537	5.20	0.30	6611	–
	4.30	73	66	308	280	63	230	69	30.16	0.537	5.20	0.28	6861	–
	A. M.													
Sept. 14	5.45	64	61	184	190	65	[illegible]	64	30.13	0.356	6.89	0.10	[illegible]	–
	6.15	66.5	62	178	175	65	206	66	30.13	0.360	[illegible]	0.10	[illegible]	–

Period of steady action, from 9*h*. 20*m*. a. m. to 3*h*. 10*m*. p. m. = 5*h*. 50*m*.; coal supplied to grate, 663.75 lbs.; water supplied to boiler, 5,171 lbs.; water to 1 of coal, 7.790.

THIAN (NEW SHAFT) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	54.4	38	-	-	Morning cloudy; wind NE., light; commenced firing; water 1.23 inch below normal level.
8.15	57.1	58	—14	-	Wood consumed, 389½ lbs.; commenced charging with coal.
8.30	57.1	64	—12	-	Steam allowed to escape at 8*h*. 20*m*.; air plates opened, and damper set at 8 inches at 8*h*. 50*m*.
-	56.9	73	-	2.495	
9.20	58.1	92	+42	3.083	Wind SE.
-	57.5	106	80	2.172	
10.10	59.9	129	60	2.659	Sun shining; filled tank at 10*h*. 56*m*.
10.40	61.1	142	67	2.188	
-	60.6	159	68	2.077	Wind E., brisk; cloudy.
11.50	60.6	170	73	2.744	
-	58.3	180	81	2.236	
0.35	62.3	197	60	2.675	
1.30	61.8	202	64	1.838	Placed 28 pounds of this coal in the drying apparatus.
-	60.6	205	74	2.236	The coal burned in this experiment chiefly in lumps.
2.33	61.1	210	92	2.156	Smoke 19 seconds in reaching chimney top; syphon 0.34.
-	61.1	220	80	2.659	Smoke at chimney top to-day after charging and stoking,
3.10	58.8	222	90	2.188	but not dense or long continued; filled tank at 3*h*. 40*m*.
-	59.5	229	63	1.616	Air plates closed; damper at 4 inches; contents of ash pit thrown on grate.
-	62.3	235	50	-	Water left at 0.3 inch above normal level.
-	58.9	120	—22	-	Water 1.6 inch below normal level.
-	57.8	111.5	—31	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	43.00
Ashes - - - - - - - - - -	52.00
Ashes behind bridge - - - - - - - -	3.00
	98.00
Deduct wood ashes - - - - - - - -	1.186
Total waste from coal - - - - - - - -	96.814
Coke - - - - - - - - - -	12.75

TABLE CXLV.—MIDLO

Second trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	Open air entering									Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 14	6.15	66.5	62	176	175	65	206	65	30.13	0.360	6.96	0.10	–	–
	7.25	[illegible]	63.5	155	286	65	227	65	30.13	0.531	[illegible]	0.22	–	92.75
	8.00	66	63	160	265	65	229	65	30.13	0.527	5.30	0.25	330	92.00
	8.45	68	65	172	310	65	231	66	30.13	0.547	5.10	0.30	603	–
	9.00	69	66	180	338	65	232	[illegible]	30.13	[illegible]	5.00	0.32	[illegible]	94.00
	9.30	70	[illegible]	196	323	65	230	67	30.13	0.537	5.20	0.29	1282	–
	10.00	71	67	208	–	65	230	68	30.12	0.537	5.20	0.30	1777	97.25
	10.30	71	67	[illegible]	–	65	232	68	30.12	0.531	5.26	0.30	2177	96.25
	11.00	72	68	242	310	[illegible]	232	68	30.11	0.540	5.17	[illegible]	2800	105.50
	11.30	73	69	258	326	65	232	[illegible]	30.11	0.536	5.21	0.34	3061	[illegible]
	P. M. 0.00	73	69	270	–	64	232	69	30.11	0.540	5.17	0.31	3605	–
	[illegible]	[illegible]	69	280	292	64	232	69	30.10	0.530	5.27	0.30	4183	95.00
	1.00	74	69	298	[illegible]	64	232	[illegible]	30.10	0.533	5.24	[illegible]	4593	–
	1.30	[illegible]	70	[illegible]	[illegible]	64	232	70	30.06	[illegible]	5.26	[illegible]	5181	91.50
	2.00	76	70	324	325	64	232	[illegible]	30.06	[illegible]	5.21	0.30	[illegible]	–
	2.30	76	70	336	324	65	[illegible]	70	30.05	0.533	5.24	0.28	[illegible]	–
	3.00	[illegible]	71	339	322	65	231	70	30.04	[illegible]	5.27	0.27	6221	89.25
	3.30	78	72	346	303	64	231	71	30.03	0.522	5.35	[illegible]	[illegible]	–
	4.00	75	70	341	[illegible]	64	230	71	30.03	0.519	5.39	0.22	6641	–
	4.30	[illegible]	70	342	260	64	230	71	30.03	0.525	5.32	0.20	6736	–
Sept. 15	A. M. 6.00	77	73	[illegible]	182	66	214	75	29.80	[illegible]	6.95	0.10	6733	–
	6.30	76	73	206	180	66	210	75	[illegible]	[illegible]	7.08	0.15	7084	–

Period of steady action, from 9h. a. m. to 2h. 35m. p. m.—5h. 35m.; coal supplied to the grate, 667.5 lbs.; water supplied to boiler, 5,277 lbs.; water to 1 of coal, 7.905.

THIAN (NEW SHAFT) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	59.0	111.5	—31	-	Morning cloudy; Wind NE., brisk; commenced firing; water at 0.6 inch below normal level.
7.25	60.5	89.5	+ 9	-	Wood consumed, 129½ lbs.; commenced charging with coal; upper damper 8 inches.
7.35	61.1	94	36	1.567	Steam blows off at 7*h*. 30*m*. a. m.; raining at 8*h*. 15*m*. a. m.
-	63.2	104	79	0.964	
9.00	64.3	111	106	0.805	
-	63.8	126	93	3.195	Continues to rain; water in boiler much agitated.
9.35	64.9	137	-	2.623	Commenced drawing gases at 9*h*. 46*m*. a. m.; drew in 44 minutes 100 cubic inches, which gave water 0.44
10.10	64.9	147	-	2.119	grain, carbonic acid 5.19 grains, oxygen 12.777 cubic
11.00	66.0	170	78	3.301	inches.
11.30	67.1	185	94	1.489	Filled tank at 11*h*. 38*m*. a. m.; commenced drawing gases again at 11*h*. 38*m*. a. m.; drew in 38 minutes 100 cubic
-	67.1	197	-	2.776	inches, which gave water 0.69 grain, carbonic acid 5.56
0.23	67.1	207	60	3.062	grains, and oxygen 8.336 cubic inches; wind E., brisk;
-	66.6	224	94	2.172	continues to rain.
1.30	67.3	240	84	3.115	
-	67.3	248	93	2.278	
-	67.3	252	92	1.536	Clinker adheres slightly to grate.
2.35	68.9	254	91	1.748	Contents of ash pit thrown on grate at 3*h*. 5*m*. p. m.; filled tank at 3*h*. 25*m*. p. m.
-	69.5	268	72	0.758	The smoke from chimney to-day about the same as yesterday.
-	67.7	266	63	-	Damper reduced to 4 inches.
-	68.6	269	30	-	Water in boiler left at normal level.
-	71.4	131	—32	-	Water 1.27 inch below normal level; boisterous morning.
-	71.8	132	—30	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	43.00
Ashes - - - - - - - - - -	47.00
Ashes behind bridge - - - - - - - - -	3.00
Total clinker and ashes - - - - - - - -	93.00
Deduct wood ashes - - - - - - - - -	0.397
Total waste from coal - - - - - - - - -	92.603
Coke - - - - - - - - - - -	14.25

TABLE CXLVI.—MIDLO

Third trial—upper damper 4 inches open; air

Date.	Hour.	TEMPERATURES OF THE: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney	Water in tank.	Steam in boiler.	Attached thermometer	Height of barometer.	Height of manometer.	Volumes of air in manometer	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
Sep			73	208	180	66	210	75	29.81	0.347	7.06	0.15	-	-
			74	182	266	66	223	[illegible]	29.84	0.461	[illegible]	0.24	-	103.25
			73	188	280	68	232	76	29.86	0.537	[illegible]	0.30	160	-
			73	188	305	68	232	76	29.87	0.535	5.22	0.30	246	94.75
			73	195	275	68	231	77	29.87	0.532	5.25	[illegible]	583	-
			74	210	275	68	230	77	29.88	0.530	5.27	0.25	920	-
			[illegible]	[illegible]	290	68	231	78	29.89	0.533	5.24	0.26	1174	94.25
			75	244	295	68	230	[illegible]	29.89	[illegible]	[illegible]	0.30	1522	-
			75	252	290	68	232	79	29.90	0.530	5.27	0.26	1773	102.00
			75	268	292	69	234	[illegible]	29.90	0.535	5.22	[illegible]	2160	-
			76	276	292	69	232	80	29.90	[illegible]	5.22	0.31	[illegible]	103.75
			74	272	-	[illegible]	232	79	29.91	0.549	5.08	0.32	2834	92.50
			75	280	290	69	233	79	29.90	0.527	5.30	[illegible]	3330	-
			76	296	304	69	233	80	29.90	0.533	5.24	0.29	3746	91.75
			77	314	308	70	233	[illegible]	29.87	0.533	5.24	0.30	4166	-
			77	318	[illegible]	70	232	81	29.88	[illegible]	5.32	0.30	4480	-
			77	324	312	[illegible]	233	81	29.88	[illegible]	5.26	[illegible]	4786	99.25
			78	326	313	70	232	81	29.89	[illegible]	5.27	0.30	5138	-
			[illegible]	326	[illegible]	70	232	82	29.88	[illegible]	5.27	0.29	5376	96.50
			[illegible]	341	310	71	232	82	29.88	0.529	5.28	0.30	5738	-
			78	343	305	71	232	83	29.89	[illegible]	5.25	[illegible]	6036	-
			78	340	-	70	232	82	29.88	0.535	5.22	0.33	6440	101.50
			78	334	296	71	232	82	29.89	0.531	5.26	0.30	6858	-
			77	356	298	71	231	[illegible]	29.90	0.525	5.32	0.30	7102	104.25
			76	361	288	71	230	80	29.91	0.519	5.38	0.29	7556	-
Sep			70	248	208	72	228	74	30.01	0.462	[illegible]	0.44	7581	-
			70	242	205	72	216	73	30.00	0.394	6.62	0.12	8093	-

Period of steady action, from 8*h*. 30*m*. a. m. to 6*h*. 10*m*. p. m. = 9*h*. 40*m*.; Coal supplied to grate in that time, 885.75 lbs.; water supplied to boiler in that time, 6,694 lbs.; water to 1 of coal, 7.557.

THIAN (NEW SHAFT) COAL.

plates open; steam escaping from both valves.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	71.8	132	— 30	-	Morning cloudy; wind SE., strong; commenced firing; water 0.55 inch below normal level.
7.37	71.7	102	45	-	Commenced charging with coal; wood consumed, 110½ lbs.
-	70.3	108	48	0.776	Steam blows off.
......	......	......			
8.30	70.3	108	73	0.675	Air plates opened; damper reduced to 4 inches; sun shining.
......			......	......	
-	70.3	115	44	1.791	At 8*h*. 50*m*. a. m. wind SW., brisk.
-	71.4	129	45	1.785	Fire out of small furnace, and its damper closed.
9.50	70.0	147	59	1.346	
-	71.8	160	65	1.849	
11.00	71.8	168	58	1.324	Filled tank at 11*h*. 22*m*. a. m.
-	71.8	184	60	2.050	
0.00	73.3	192	60	1.791	Commenced drawing gases at 0*h*. 4*m*. p. m., drew in 30 minutes 100 cubic inches, which gave water 0.69 grain,
0.15	71.4	191	-	1.781	carbonic acid 4.29 grains, oxygen 13.93 cubic inches.
-	72.2	197	57	2.628	Lower damper open whilst drawing gases; weather vari-
1.37	73.1	211.5	71	2.215	able; wind SW., brisk.
-	74.1	228	75	2.215	Fire rekindled in small furnace.
-	73.8	231	76	1.663	Smoke 22 seconds in reaching chimney top; clear; wind
2.40	74.1	238	79	1.621	SW., brisk.
-	74.6	237	81	1.865	
4.00	74.9	238	62	1.261	
-	74.6	252	78	2.183	
-	74.9	255	73	1.324	Afternoon continues clear; wind brisk, S.; filled tank at 5*h*. 18*m*. p. m.
5.10	74.6	251	-	2.129	Commenced drawing gases through lower flue at 5*h*. 14*m*. p. m.; drew in 28 minutes 100 cubic inches, which gave water 0.7 grain, carbonic acid 4.56 grains; oxygen 12.381
-	74.9	246	64	2.215	cubic inches.
6.10	73.2	267	67	1.293	Air plates closed, and contents of ash pit thrown on grate.
......	......		......	......	
-	72.7	275	58	-	Water left 1 inch above normal level.
-	67.7	173	— 15	-	Water found 1.8 inch below normal level.
-	67.7	166	— 11	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
linker - - - - - - - - - -	40.25
shes - - - - - - - - - -	67.25
shes behind bridge - - - - - - - -	3.00
tal ashes and clinker - - - - - - - -	110.50
duct wood ashes - - - - - - - -	0.339
tal waste from coal - - - - - - - -	110.161
ke - - - - - - - - - -	24.25
ot - - - - - - - - - -	14.00

TABLE CXLVII.—DEDUCTIONS

Experiments on Midlo

	Nature of the data furnished by the respective tables.	1st Trial. (*Ta. CXLIV.*)	2d Trial (*Ta. CXLV.*)
		September 13.	*September* 14.
1	Total duration of the experiment, in hours	24.667	24.083
2	Duration of steady action, in hours	5.833	5.583
3	Area of grate, in square feet	14 07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	10 0	10.0
7	Total weight of coal supplied to grate, in pounds	939.75	946.25
8	Pounds of coal actually consumed	927.0	932.0
9	Pounds of coal withdrawn and separated after trial	12.75	14.25
10	Mean weight, in pounds, of 1 cubic foot of coal	46.9875	47.3125
11	Pounds of coal supplied per hour, during steady action	113.8	119.56
12	Pounds of coal per square foot of grate surface, per hour	8.088	8.497
13	Total waste, ashes and clinker, from 100 pounds of coal	10.443	9.935
14	Pounds of clinker alone, from 100 pounds of coal	4.5818	4.5949
15	Ratio of clinker to the total waste, per cent.	43.871	46.245
16	Total pounds of water supplied to the boiler	7396.0	7084.0
17	Mean temperature of water, in degrees Fahrenheit	64°.5	64°.4
18	Pounds of water supplied at end of experiment, to restore level	535.0	351.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	75.0	49.0
20	Pounds of water evaporated per hour, during steady action	886.5	954.19
21	Cubic feet of water per hour, during steady action	14.18	15.12
22	Pounds of water per square foot of heated surface per hour, by one calculation	2 348	2 504
23	Pounds of water per sq. ft., by a mean of several observations	2.385	2.515
24	Water evaporated by 1 of coal, from initial temp., (a) final result	7.897	7.5483
25	Water evaporated by 1 of coal, from initial temp., (b) during steady action	7.79	7.906
26	Pounds of fuel evaporating 1 cubic foot of water	7.9144	8.2226
27	Mean temperature of air entering below ash pit, during steady pressure	72°.07	72°.71
28	Mean temp. of wet bulb thermometer, during steady pressure	64°.05	68°.29
29	Mean temperature of air, on arriving at the grate	243°.92	258°.57
30	Mean temperature of gases, when arriving at the chimney	302°.43	319°.27
31	Mean temperature of steam in the boiler	231°.23	231°.57
32	Mean temperature of attached thermometer	68°.23	68°.43
33	Mean height of barometer, in inches	30.177	30.098
34	Mean number of volumes of air in manometer	5.0284	5.30
35	Mean height of mercury in manometer	0.5547	0.537
36	Mean height of water in syphon draught gauge, in inches	0.370	0.3009
37	Mean temperature of dew point, by calculation	60°.207	66°.13
38	Mean gain of temperature by the air, before reaching grate	171°.85	185°.86
39	Mean difference between steam and escaping gases	71°.6	88°.5
40	Water to 1 of coal, corrected for temperature of water in cistern	7.897	7.5483
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	9.0279	8.63
42	Pounds of water, from 212°, to 1 cubic foot of coal	424.2	408.29
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	10.0806	9.5816
44	Mean pressure, in atmospheres, above a vacuum	1.4485	1.4018
45	Mean pressure, in pounds per square inch, above atmosphere	6.624	5.934
46	Condition of the air plates at the furnace bridge	Open.	Closed.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

FROM TABLES CXLIV, CXLV, CXLVI.

thian (new shaft) coal.

3d Trial. (*Tā. CXLVI.*)	Averages.	Remarks.
September 15.		
24.083		
9.667		
14.07		
377.5		
18.75		
11/0		
1083.75		
1059.5		
24 25	17.083	The coke left on the grate in the 3d trial, when the combustion was conducted slowly, with a 4-inch damper, is nearly double as much as was left in either of the other trials.
49.26	47.853	
91.63	108.33	
6.228	7.604	
10.397	10.2583	
3.4644	4.2137	
36.426	42.1807	
8093.0		
69°.7		
533.0		
73.0		
692.46	844.383	
11.08	13.46	
1.834	2.229	
1.817		
7.568	7.6711	
7.557	7.75	
8.2585	8.1318	
85°.02		
75°.95		
287°.19	263°.227	
297°.47	306°.39	On the 2d trial, the gases passed into the chimney at 17° higher temperature than on the 1st.
231°.86		
79°.84		
29.888		
5.249		
0.5321		
0.2956	0.3221	
72°.91		
202°.17	186°.627	
65°.22	75°.107	
7.5508	7.6654	
8.594	8.7506	
423.34	418.61	
9.5911	9.7511	The open air plate in the 1st trial, together with the clean surface of the boiler and flues, appear to have contributed to the efficiency of the fuel about 5 per cent. more than was obtained on the 2d trial, when the plate was closed, and the surfaces partly coated with soot.
1.4068	1.419	
6.007	6.1885	
Open.		
U. 4		

No. 10.

Bituminous screened coal, from the Midlothian Company's mines of Virginia.

Information relative to this sample is conveyed in the letter of Mr. Wooldridge, already copied, in connexion with the sample of *average* coal from the same mines.

It was generally in large lumps, appearing to have but little tendency to disintegrate. Its color is mostly deep black, but diversified by scales of carbonate of lime, which incrust the main and cross partings.

The conchoidal fracture, shining or resinous lustre, and the difficulty of procuring fractures of much extent following the surfaces of deposition, are observable in this, as in other samples of Virginia coal.

The specific gravity of one specimen (*a*) was found to be 1.2906, that of another (*b*) 1.2763. The mean of these gives the calculated weight per cubic foot in the mine, 80.21 pounds. As the result of 46 trials, by measuring and weighing in the charge box, the least weight per cubic foot was 39.875; the greatest, 53.75; and the average 45.722 pounds, or exactly 57 per cent. of the weight derived from the specific gravity.

The space for stowing one ton is 48.992 cubic feet. The moisture in specimen *a* was 0.902, that in *b* 0.888 per cent. In the larger operations in the steaming apparatus, 28 pounds lost 0.5 pound in two days' drying, or 1.785 per cent.

The sulphur in specimen *a* was 0.2025 per cent.

The total volatile matter in *a*, by two trials, was 40.117; in *b*, by one trial, 33.26 per cent.

By the mean of four trials on each of the specimens, *a* yielded of earthy matter 7.37, and *b* 3.2 per cent. Hence, the proximate constituents are in—

	Specimen *a*.	Specimen *b*.
Moisture	0.902	0.888
Sulphur	0.202	(not tried.)
Other volatile matter	39.013	32.372
Earthy matter	7.370	3.200
Fixed carbon	52.513	63.540
	100.	100.
Volatile to fixed combustible	1:1.346	1:1.9583

In two specimens examined by Dr. King, the total volatile matter was found to be 35.875 per cent. This number, combined with the two above, gave for the average of volatile matter, including moisture, 36.2817. During the trials on evaporation, there were burned 4,132 pounds of this sample, yielding as *waste*—

Of ashes	285.000 pounds.
Of clinker	142.250 "
Of soot	34.875 "

The ashes contained 13.172 per cent. of combustible matter intermixed; and the soot, of volatile matter, 13.831; fixed carbon, 50.449;

and of ashes, 35.72 per cent. Reducing the ashes and soot in the proportions here indicated, and deducting 4.09 pounds of wood ashes, we obtain 398.93 pounds as the absolute waste from the coal burned. This is equal to 9.655 per cent. Hence, the proximate constituents of the *sample* are—

Moisture, (from 28 pounds) - - -	1.785	per cent.
Other volatile matter, (4 specimens) - -	34.497	"
Earthy matter, (from 4,132 pounds) - -	9.655	"
Fixed carbon, (calculated by difference) -	54.063	"
	100.	

Volatile to fixed combustible 1 : 1.5672.

The clinker is of a deep iron-gray color, generally in small lumps, with small shaly portions. It weighs 39.37 pounds per cubic foot.

The calcined clinker becomes of a deep reddish-brown; the ashes, after reincineration, are of a "red-gray" color; the residue of the soot is of a deeper color than that of the ashes, while that left during the analyses of the coal is of a dirty-white color. The ashes weigh 53.40, and the soot 4.91 pounds per cubic foot.

With oxide of lead, specimen *a* gave 27.285 times its weight of metallic lead; or, deducting 8.272 per cent. for moisture and earthy matter of the specimen, the lead to one of *combustible matter* is 29.745.

The trial made in a smith's forge proved this sample to be superior to the average Midlothian coal, then in use in the shops. It gave a good hollow fire, with a moderate amount of cinder, a long flame, and a pretty rapid heat, with less smoke than was visible in the other fires. It did not appear to affect injuriously the iron to which its heat was applied.

It is unnecessary to state more in regard to the trial of this coal in an office grate, than that it behaved in all respects like the other samples of coal furnished by the Midlothian company—burning with long bright blaze, leaving a coke moderately durable, and producing brilliant jets of highly luminous flame, especially after the coking process had proceeded nearly to its completion.

The time required to bring the boiler into steady action was, on an average, 1.289 hour.

The average quantity of coke left unburnt, when the fire became extinct, was 14.08 pounds.

In noting its behaviour in the furnace, it was remarked that this coal cokes completely, running together into large masses, which cohere firmly during the greater part of the time of combustion, giving off a dense flame with much smoke.

Like nearly all the other samples of coal from the same district of country, it is unfit for use in the blast furnace for smelting iron, without the preliminary process of coking.

TABLE CXLVIII.—MIDLO

First trial—upper damper 12

Period of steady action this day, from 1*h*. 45*m*. to 6*h*. 15*m*. p. m. = 4*h*. 30*m*.; coal supplied to the grate, 364.75 pounds; water supplied to boiler, 2,536 pounds; water to one of coal, same period, 6.953.

THIAN (SCREENED) COAL.

inches open; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	-	-	—28	-	Kindled fire.
-	-	-	—28	-	Wood consumed, 460 pounds; steam at equilibrium; commenced charging with coal; steam blows off at 11*h*. 50*m*.
12.00	-	-	—27		
0.50	-	105	—23	0.895	New thermometer back of grate.
-	-	138	—15	0.927	
1.45	-	181.5	—13	1.589	Repaired small furnace, and kindled fire in it.
-	-	221	— 2	1.544	
3.00	-	238	+13	1.509	
-	-	259	14	1.377	Placed 28 pounds of this coal in the drying apparatus.
4.15	-	293	14	1.519	
-	-	318	20	1.819	
5 30	-	321	30	0.901	Smoke 31 seconds in reaching chimney top.
-	-	323	33	-	Filled tank.
6.15	-	329.5	27	1.654	Coal generally in lumps.
-	-	334	35	-	Contents of ash pit thrown on grate; water 1.6 inch above normal level.
-	-	156	—27	-	Some fire on grate; water 1.45 inch below normal level.
-	-	150	—22	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	18.75
Ashes	46.75
Ashes behind grate	4.87
Total clinker and ashes	70.37
Deduct wood ashes	1.408
Total waste from coal	68.962
Coke	15.25

TABLE CXLIX.—MIDL

First trial—upper damp

Period of steady action, from 10*h*. 30*m*. a. m. to 6*h*. p. m.—7*h*. 30*m*.; coal supplied to gr
645.25 lbs.; water to boiler, during same period, 4,326 lbs: water to 1 of coal, 6.703.

THIAN (SCREENED) COAL.

6 inches open ; air plates removed.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 16.25 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					
-	54.3	150	—22	-	Commenced firing; water at normal level.
-	55.0	132	+17	-	Wood consumed, 118¾ lbs.; commenced charging with coal.
8.05	55.0	132	22	-	Damper fully open at 8*h.* 5*m.* a. m.; steam blows off, and damper then reduced to 6 inches.
-	53.0	140	32	1.219	
9.15	51.6	153	41	1.144	
-	49.5	181	51	0.795	
10.30	53.0	212.5	52	2.285	
-	48.0	224	62	1.775	Filled tank at 11*h.* 20*m.* a. m.
11.40	48.0	254	60	0.596	
0.20	50.2	294	64	1.927	Smoke 27.5 seconds reaching chimney top.
-	50.2	302	63	1.708	
1.25	50.2	312	68	2.162	
-	51.0	331	66	1.121	
2.45	54.5	333	75	1.360	Smoke 26 seconds in reaching chimney top.
3.35	49.8	343	68	2.066	Tank filled at 3*h.* 55*m.* p. m.
-	49.8	349	58	1.839	Smoke dense to-day while charging.
4.45	49.8	355	58	1.184	
-	51.0	347.5	54	0.901	
6.00	48.5	358	62	1.625	Contents of ash pit thrown on grate.
-	47.6	357	62	-	Water left at 1.35 inch above normal level.
-	46.5	183	—20	-	Water found at 1.95 inch below normal level.
-	43.9	-	—18	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	31.75
Ashes	60.25
Ashes behind bridge	7.13
Total clinker and ashes	99.13
Deduct wood ashes	0.363
Total waste from coal	98.767
Coke	21.25
Soot	1.375

TABLE CL.—MIDLO

Third trial—upper damper 12 *inches*

Date.	Hour.	TEMPERATURES: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.					Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal
	h. m. A. M.													
May 19	5.35	55	51	112	175	63	[illegible]	–	30.17	–	–	0.11	–	–
	7.30	57	52	140	[illegible]	64	225	–	30.16	0.149	9.14	0.11	–	–
	7.45	57	52	–	224	64	227	–	30.16	0.163	8.96	0.12	–	89.50
	7.50	59	52	127	225	64	227	–	30.16	0.175	8.84	0.14	–	–
	[illegible]	58	51	–	270	64	229	–	30.16	0.161	8.78	0.15	65	–
	9.05	60	52	–	263	64	228	–	30.16	0.161	8.78	0.16	340	95.75
	9.40	60	52.5	134	288	64	229	–	30.16	0.165	8.74	0.13	760	–
	10.10	61	52	174	292	64	229	–	30.16	0.163	8.76	0.14	930	–
	10.40	62	51.5	192	290	[illegible]	228	–	30.16	0.162	8.77	0.15	1270	79.75
	11.20	62.5	52.5	202	288	[illegible]	229	–	30.16	0.163	8.76	0.16	1355	82.50
	P. M.													
	0.00	63	53	210	304	64	230	–	30.15	0.183	8.76	0.15	1780	–
	0.25	63	52	218	310	64	229	–	30.13	0.189	8.70	0.15	2035	83.75
	1.00	63	53	226	316	[illegible]	229	–	30.13	0.182	8.77	0.14	2415	–
	1.30	63	53	240	315	65	229	–	30.12	0.176	8.83	0.15	2695	81.25
	2.00	64	53	246	290	65	[illegible]	–	30.13	0.181	8.78	0.17	2935	–
	2.50	62	53.5	254	316	65	229	–	30.12	0.189	8.70	0.17	3270	89.00
	3.15	64	53	258	322	65	228	–	30.12	0.187	8.72	0.16	3555	–
	3.45	64	53	264	343	65	229	–	30.11	0.182	8.77	0.17	3985	–
	4.20	63	54	268	317	66	229	–	30.11	0.187	8.72	0.17	4320	84.00
	4.50	63	55	270	330	64	229	–	30.11	0.181	8.78	0.20	[illegible]	–
	[illegible]	63	55	272	326	64	229	–	30.11	0.190	8.69	0.19	4810	82.50
	5.45	63	55	272	324	64	229	–	30.10	0.182	8.77	0.18	5070	–
	6.15	62	54	278	328	[illegible]	228	–	30.12	0.189	8.70	0.18	5410	–
	6.40	60	53	278	336	64	229	–	30.10	0.196	8.62	0.19	5740	85.50
	7.00	60	52	276	344	64	229	–	30.12	0.187	8.72	0.16	6090	–
	7.30	61	53	280	332	64	[illegible]	–	30.11	0.189	8.70	0.16	6250	–
	[illegible]	61	53.5	288	332	64	229	–	30.11	0.187	8.72	[illegible]	6600	96.25
	8.30	60	53	281	337	65	229	–	30.11	0.183	8.76	0.19	6940	–
	9.00	61	53	290	336	64	228	–	30.11	0.181	[illegible]	0.20	7190	–
	9.30	60	53	[illegible]	335	64	226	–	30.11	[illegible]	8.76	0.19	7350	90.75
	9.45	60.5	53	304	322	[illegible]	226	–	30.11	0.169	8.90	0.19	7485	–
	A. M.													
May 20	5.20	55	51.5	224	196	64	216	–	30.00	–	–	0.12	7485	–
	5.50	55	–	216	191	64	210	–	[illegible]	–	–	0.11	8310	–

Period of steady action, from 10*h.* 40*m.* a. m. to 9*h.* 30*m.* p. m.—10*h.* 50*m.*; coal supplied to grate, 775.5 lbs.; water to boiler, 6.080 lbs.; water to 1 of coal for the same period, 7.84.

THIAN (SCREENED) COAL.

open ; air plates open ; coking plate on.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 11.375 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.	°				
-	46.3	57	—27	-	Commenced firing; water at normal level.
-	46.5	83	— 7	-	Wood consumed, 159 lbs.; commenced charging with coal.
7.45	46.5	-	— 3	-	Steam at equilibrium; upper damper at 16 inches.
-	45.4	69	— 2	-	Steam begins to blow off; air plates opened.
-	42.9	-	+41	0.338	
9.05	43.2	-	55	1.158	
-	44.4	74	59	1.907	Drew gas at 10*h.* 0*m.*, found it incombustible; slight smoke from chimney.
-	42.2	113	63	0.901	
10.40	39.7	130	62	1.801	
11.20	41.9	139.5	59	0.338	
-	42.7	147	74	1.689	
0.25	40.1	155	81	1.621	
-	42.7	163	87	1.726	
1.30	42.7	177	86	1.483	
-	41.7	182	61	1.271	Little smoke from chimney.
2.50	45.0	192	87	1.065	
-	41.7	194	94	1.812	Gases 22 seconds in reaching chimney top.
-	41.7	200	94	2.278	
4.20	45.1	205	88	1.521	Filled tank at 4*h.* 35*m.*
-	47.6	207	101	1.722	
5.20	47.6	209	97	0.874	Coal in drying apparatus weighs 27 lbs. 8 oz.
-	47.6	209	95	1.653	
-	46.2	216	100	1.801	
6.40	45.7	218	109	2.098	
-	43.2	218	115	3.046	
-	44.7	219	103	0.848	
8.00	45.9	227	103	1.854	
-	45.7	221	108	1.801	
-	44.7	229	108	1.325	Coal to-day chiefly lumps.
9.30	45.7	231	109	0.848	Contents of ash pit thrown on grate.
-	45.2	243.5	96	1.460	Air plates closed; damper set at 6 inches.
-	45.0	169	—20		
-	-	163	—19	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	39.00
Ashes - - - - - - - - - - -	47.25
Ashes behind bridge - - - - - - - -	10.75
	97.00
Deduct wood ashes - - - - - - - -	0.488
Total waste from coal - - - - - - - -	96.512
Coke - - - - - - - - - - -	8.50

TABLE CLI.—MIDLO

Fourth trial—upper damper 6 inches

Period of steady action, from 9*h*. 50*m*. a. m. to 4*h*. p. m.—6*h*. 10*m*.; coal supplied to grate, 449 lbs.; water to boiler, 3,710 lbs; water to 1 of coal, same period; 8.261.

THIAN (SCREENED) COAL.

open; air plates open; coking plate on.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 11.375 square feet; length of circuit of heated gases 121 feet; height of chimney 41 feet.
h. m.					Commenced firing.
-	-	163	—19	-	Wood consumed, 135½ lbs.; commenced charging with coal; steam at equilibrium.
-	-	139	-	-	Steam begins to blow off; air plates opened at 7*h.* 45*m.* a. m.; ash pit doors left open 25 minutes, closed at 7*h.* 55*m.* a. m.
7.30	48.1	136			
-	46.2	142	+68	0.424	Upper dampers set at 6 inches at 8*h.* a. m.
-	43.9	144.5	67	1 351	
9.00	45.0	145.5	59	2.106	
9.50	46.5	164	78	1.192	Filled tank.
-	46.5	179	83	2.225	
-	45.7	190	87	1.708	Smoke 25 seconds in reaching chimney top.
11.20	45.3	196.5	86	1.311	
-	45.7	198	77	1.371	
0.30	43.2	202	87	0.450	
-	42.4	209	85	2.225	
1.35	44.7	220.5	101	1.953	
-	43.6	223	104	2.193	
2.40	42.4	227	93	1.271	
-	43.6	238	-	1.135	Coal in drying apparatus weighs 27 lbs. 8½ ounces.
4.00	44.7	232.5	90	1.766	Coal burned to-day generally in lumps.
-	42.4	247	85	2.543	Contents of ash pit thrown on grate.
-	42.4	251	63	-	Filled tank; water in boiler left at 0.75 inch above normal level.
-	49.1	136.25	—24		
-	-	-	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	15.25
Ashes	46.25
Ashes behind bridge	7.75
	69.25
Deduct wood ashes	0.385
Total waste from coal	68.865
Coke	7.875
Soot	30.875

TABLE CLII.—MIDLO

Fifth trial—upper damper 8 inches open; air plates open;

Period of steady action, from 11*h.* 3*m.* a. m. to 4*h.* 8*m.* p. m.—5*h.* 5*m.*; coal supplied to furnace, same time, 609 lbs.; water to boiler, 4,485.13 lbs.; water to 1 of coal, 7.365.

THIAN (SCREENED) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	49.7	47	—10	-	Commenced firing at 6*h.* 29*m.*; wind E., brisk, and raining.
-	50.8	46	+40	-	Raining violently.
-	50.3	56.5	44		
-	53.0	67	12		
-	52.0	67	2		
9.50	54.5	69.5	15	-	Wood consumed, 440¼ lbs.; commenced charging with coal.
-	53.1	70	3	-	Steam allowed to blow off at 10*h.* 0*m.*; just after taking observation, wind SE.
10.24	55.3	74	23	1.854	Air plates opened at 10*h.* 22*m.*
11.03	56.3	88	68	2.585	Steam allowed to escape from back valve.
-	58.5	102	65	1.716	Wind SW., clearing off; again clouding up at 11*h.* 25*m.*, followed by rain; wind W.
11.47	59.3	122	69	2.210	Filled tank; grate bars red; clearing off at 11*h.* 55*m.*; wind SW., light.
0.27	62.7	139	71	2.517	Commenced drawing gases at 0*h.* 32*m.*, (fire in good action, with fresh coal on;) drew in 56 minutes 100 cubic inches,
-	58.7	149	87	2.399	which gave water 0.40 grain, carbonic acid 5.58 grains,
1.35	57.5	159	90		oxygen 10 cubic inches; water 0.6 inch below normal
-	54.0	169	86	2.140	level at 1*h.* 30*m.*; filled tank at 1*h.* 45*m.*; wind NW.,
2.27	57.0	175	90	2.872	brisk; sun shining. Smoke in reaching chimney top, (upper damper,) first trial 12.5 seconds; syphon 0.41; sec-
-	51.0	179	116	2.681	ond trial 14 seconds; (through lower damper,) first trial
3.04	48.8	187	105	2.209	8.5 seconds, syphon 0.42; second trial 8 seconds.
4.08	49.6	194	104	2.421	
-	48.8	202	100	2.315	Contents of ash pit thrown on grate; air plates closed; damper set at 4 inches at 5 o'clock; wind NW., very light.
-	41.7	209	89	1.701	
-	40.1	222	56	0.836	
-	37.2	220	49	-	Water 1.2 inch above normal level.
-	33.3	190	—16	-	Too much water in boiler, and the level is produced by drawing out.
-	22.7	137	—36		
-	-	73	—38	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	37.5
Ashes	52.5
Ashes behind bridge	1.5
	91.5
Deduct wood ashes	1.352
Total waste from coal	90.148
Coke	21.5
Soot	4.00

TABLE CLIII.—DEDUCTIONS FROM

Experiments on Midlo

	Nature of the data furnished by the respective tables.	1st Trial. (Table CXLVIII.)	2d Trial. (Table CXLIX.)
		May 16.	*May* 17.
1	Total duration of the experiment, in hours	24.082	24.25
2	Duration of steady action, in hours	4.5	7.50
3	Area of grate, in square feet	16.25	16.25
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	21.66	21.66
6	Number of charges of coal supplied to grate	7.0	10.0
7	Total weight of coal supplied to grate, in pounds	626.75	919.5
8	Pounds of coal actually consumed	611.36	899.04
9	Pounds of coal withdrawn and separated after trial	15.39	20.46
10	Mean weight, in pounds, of one cubic foot of coal	44.767	45.975
11	Pounds of coal supplied per hour, during steady action	81.05	86.03
12	Pounds of coal per square foot of grate surface, per hour	4.987	5.294
13	Total waste, ashes and clinker, from 100 pounds of coal	11.2795	10.9858
14	Pounds of clinker alone, from 100 pounds of coal	3.0097	3.5204
15	Ratio of clinker to the total waste, per cent.	26.683	31.726
16	Total pounds of water supplied to the boiler	4733.0	7015.0
17	Mean temperature of water, in degrees Fahrenheit	76°.5	73°.7
18	Pounds of water supplied at the end of experiment, to restore level	645.0	815.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	85.0	112.0
20	Pounds of water evaporated per hour, during steady action	563.30	576.66
21	Cubic feet of water per hour, during steady action	9.01	9.226
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.492	1.527
23	Pounds of water per square foot, by a mean of several observations	1.467	1.5225
24	Water evaporated by 1 of coal, from initial temp. (a) final result	7.619	7.678
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	6.953	6.703
26	Pounds of fuel evaporating one cubic foot of water	8.2032	8.1402
27	Mean temp. of air entering below ash pit, during steady pressure	80°.8	66°.44
28	Mean temp. of wet bulb thermometer, during steady pressure	–	–
29	Mean temperature of air, on arriving at the grate	343°.0	347°.0
30	Mean temperature of gases, when arriving at the chimney	242°.3	288°.37
31	Mean temperature of steam in the boiler	230°.2	230°.0
32	Mean temperature of attached thermometer	78°.0	64°.0
33	Mean height of barometer, in inches	29.96	30.128
34	Mean number of volumes of air in manometer	8.942	8.808
35	Mean height of mercury in manometer, in atmospheres	0.165	0.178
36	Mean height of water in syphon draught gauge, in inches	0.1487	0.1766
37	Mean temperature of dew point, by calculation	–	–
38	Mean gain of temperature by the air, before reaching grate	262°.2	280°.56
39	Mean difference between steam and escaping gases	19°.125	63°.16
40	Water to 1 of coal, corrected for temp. of water in cistern and boiler	7.691	7.6336
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern and boiler	8.7027	8.6564
42	Pounds of water, from 212°, to 1 cubic foot of coal	389.6	397.977
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	9.8092	9.7247
44	Mean pressure, in atmospheres, above a vacuum	1.4211	1.4197
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.22	6.198
46	Condition of the air plates at the furnace bridge	Removed.	Removed.
47	Inches opening of damper, (U. upper)	U. 12	U. 6

TABLES CXLVIII, CXLIX, CL, CLI, CLII.

thian (screened) coal.

3d Trial. (Table CL.)	4th Trial. (Table CLI.)	5th Trial. (Table CLII.)	Averages.	Remarks.
May 19.	*May* 20.	*November* 11.		
24.25	24.082	25.416		
10.833	6.167	5.083		
11.375	11.375	14.07		
377.5	377.5	377.5		
15.156	15.156	18.75		
12.0	8.0	9.0		
1040.25	729.25	890.75		
1031.51	721.34	869.25		
8.74	7.91	21.50	14.8	
43.344	45.575	48.9305	45.7183	
71.587	72.65	119.81	86.22	
6.013	6.387	8.515	6.2392	
9.3655	9.5469	10.1983	10.2752	
3.7615	2.1016	4.2519	3.329	
40.0	22.014	41.693	32.4232	
8210.0	6120.0	6568.0		
64°.0	62°.9	55°.3		
725.0	415.0	0.0		
102.0	58.0	0.0		
561.25	601.70	882.375	632.103	
8.583	9.627	14.118	10.1128	The first four trials were made with the chimney 41, the fifth with it 63 feet high.
1.421	1.594	2.337	1.6742	
1.556	1.601	2.351		
7.8604	8.404	7.555	7.8232	
7.8406	8.281	7.365	7.4289	
7.9513	7.4369	8.2727	8.0009	
61°.79	67°.43	67°.0		
53°.5	55°.36	59°.86		
248°.5	261°.2	228°.54	285°.648	
326°.4	312°.73	319°.09	297°.778	
228°.73	228°.86	229°.73		
59°.0	65°.0	61°.64		
30.126	29.94	29.524		
8.743	8.821	5.007		
0.1845	0.177	0.557		
0.1736	0.21	0.385	0.1788	
47°.3	44°.9	55°.08		
186°.71	193°.77	161°.54	216°.956	
93°.28	89°.3	88°.30	70°.633	
7.8991	8.404	7.555	7.8365	
9.0341	9.6206	8.7066	8.9441	
391.575	438.46	426.01	408.725	
9.9677	10.636	9.714	9.9703	
1.4236	1.4192	1.4436	1.4255	
6.2565	6.1919	6.5509	6.2835	
Open. U. 12	Open. U. 6	Open. U. 8		

Remarks on the preceding table of deductions.

The sample to which this table relates was burned at five trials, of which four were made with the chimney 41 feet, and one with it 63 feet high. To prove the relation which exists between the *average* and the *screened* coal from the same mines, a comparison may be instituted between the 21st line of this table, and the line having the same number in table CXXXVII. In the last-mentioned table, the 2d and 5th trials are comparable with the 1st and 3d of the preceding table. The mean rate of evaporation by the *average* coal is seen to be 10.108; that of the *screened* 8.796 cubic feet of water per hour. It appears from this, that the screened coal was inferior in activity to the average.

In speaking of the draught of the chimney, in a former part of this report, the causes of the velocity of motion of gases are enumerated, (see page 19.) It may here be added, that the *height* of a chimney is a most important element in computing the force and velocity of gases flowing through it, and of determining, when all other circumstances are equal, the rate of combustion in any furnace connected with it. The table of deductions now under consideration affords proof of this assertion: On the 19th of May, with a chimney 41 feet high, air plate open, and damper drawn twelve inches, the combustion was at the rate of 6.013 pounds of coal per square foot of grate per hour. On the 11th of November, with a chimney 63 feet high, damper drawn but eight inches, and air plate also open, the combustion was 8.515 pounds per square foot of grate per hour. The evaporation from the boiler on the 19th of May was 8.583 cubic feet per hour, or 0.754 of a cubic foot to one square foot of grate—the area of the latter being then 11.375 square feet. On the 11th of November it was 14.118 cubic feet of water per hour from the boiler; and as the grate was 14.07 square feet, it was 1.003 cubic foot of water to one square foot of grate. The gain in the combustion on a square foot of grate is here 41 per cent.

No. 11.

Midlothian average coal, taken promiscuously from a heap procured for use in the smith shops at the Washington navy yard.

On this sample of coal, two imperfect experiments were made while testing the condition and action of the apparatus. Having been performed under considerable disadvantages in respect to the means and appliances for observation, which had not then been fully completed, and without the necessary assistance to take, simultaneously, the several classes of notes, I have not deemed it necessary to detail the observations. In all its external characters, the coal was very similar to other samples from the Midlothian mines.

A quantity of this sample was used in composing the *mixtures* of Midlothian and Beaver Meadow coals, of which a detailed account has already been given.

The following table shows the composition and other properties of this, as well as other Virginia coals. The per centage of clinker derived from the two trials above referred to, is among the data there recorded. The total waste from one of the experiments was 20.1 per cent. The samples *sent for trial* by the Midlothian Company gave for the highest result, in *waste*, 14.83 per cent.; and for the average of four samples, 11.514 per cent.; another evidence of some deficiency in preparing coal for the market.

TABLE CLIV.—*Synoptical view of the characters, composition, and efficiency, of Virginia bituminous coals.*

Designation of coals.	Density.						Composition, in 100 parts.						
	Specific gravity.	Pounds per cubic foot, calculated from specific gravity.	Number of experiments, to determine actual weight.	Weight, in pounds per cubic foot, by experiment.	Ratio of actual to calculated weight.	Cubic feet of space required to stow one ton.	Moisture, determined by steam drying apparatus.	Volatile matter, other than moisture.	Sulphur.	Fixed carbon.	Coke.	Earthy matter.	Ratio of fixed to volatile combustible matter.
Barr's Deep Run - - -	1.382	86.410	48	53.174	0.6153	42.126	1.785	19.782	–	67.958	78.433	10.475	3.435
Crouch & Snead's - - -	1.451	90.710	36	53.593	0.5908	41.797	1.785	23.959	0.427	59.976	74.256	14.280	2.499
Midlothian (900 ft. shaft) average coal	1.437	87.497	34	50.518	0.5773	44.340	1.172	27.278	–	61.083	71.550	10.467	2.239
Creek Company's coal - -	1.319	82.480	41	46.496	0.5636	48.170	1.450	29.678	2.890	60.300	68.872	8.572	2.032
Clover Hill - - - -	1.285	80.355	42	45.485	0.5660	49.250	1.339	31.698	0.514	56.831	66.963	10.132	1.793
Chesterfield Mining Company -	1.289	80.565	43	45.549	0.5653	49.180	1.896	30.676	1.957	58.794	67.428	8.634	1.917
Midlothian, average - -	1.294	80.895	42	54.044	0.6680	41.450	2.455	29.796	0.058	53.012	67.749	14.737	1.780
Tippecanoe - - -	1.346	84.140	55	45.100	0.5360	49.670	1.841	34.165	0.377	54.620	63.994	9.374	1.599
Midlothian, "new shaft" - -	1.325	82.815	31	47.899	0.5811	46 760	0.670	33.490	2.286	56.400	65.840	9.440	1.684
Midlothian, screened - -	1.283	80.210	46	45.722	0.5700	43.990	1.785	34.497	0.202	54.063	63.718	9.655	1.567
Midlothian, (navy yard) - -	1.390	86.855	15	54.468	0 6271	41.125	1.014	28.736	2.380	56.112	70.250	14.138	1.953

1,436. 29,432 1,232 58,113, 10,503

SYNOPTICAL TABLE CLIV—Continued.

Designation of coals.	Combustion.				Action of furnace during steady pressure.					Evaporation.					
					Mean temperature						Pressure		Water supplied per hour, during steady action.		
	Total No. of pounds consumed.	Pounds supplied per hour, during steady action.	Pounds per square foot of grate surface per hour, during steady action.	Pounds evaporating one cubic foot of water.	Of air, on arriving at grate	Of gases, on arriving at chimney.	Gained by the air, before reaching grate.	Of escaping gases above that of steam in boiler.	Draught gauge—height, in inches, of water.	Time required to bring boiler to steady action, in hours.	In atmospheres, above a vacuum.	In pounds per sq. inch, above 1 atmosphere.	In pounds.	In cubic-feet.	In pounds per square foot of absorbing surface of boiler.
Barr's Deep Run - -	5072.75	106.93	7.600	7.992	222.87	328.68	163.02	96.53	0.382	1.520	1.436	6.444	838.93	13.421	2.218
Crouch & Snead's - -	3834.75	97.90	7.133	8 576	199.66	306.87	133.71	81.78	0.359	1.158	1.417	6.165	724 41	11.649	2.071
Midlothian (900 ft. shaft) average coal	3417.50	122.10	8.678	8.348	247.13	348.61	179.90	114.90	0.367	1.383	1.421	6.222	907.11	14.513	2.403
Creek Company's coal - -	3769.63	120.94	8.595	8.445	276.49	337.89	196 76	114.14	0.318	1.166	1.431	6.367	930.40	14.885	2 464
Clover Hill - - -	3775.10	89.56	5.843	9.340	362.51	302.54	297.95	74.81	0.145	1.933	1.416	6.144	521.89	8.348	1.382
Chesterfield Mining Company's -	3876.00	119.02	8.459	9.069	252.01	344.58	172.28	113.72	0.299	1.166	1.437	6.461	909.74	14.467	2.409
Midlothian, average - -	4506.39	90.27	6.676	8.756	247.72	289.01	171.89	65.07	0.214	1.516	1.436	6.441	630.71	10.091	2.019
Tippecanoe - - -	4904.75	108.95	7.369	9.361	325.25	302.15	266.66	72.11	0.231	1.333	1.426	6.291	663.59	10.622	1.757
Midlothian, "new shaft" - -	2918.50	108.33	7.604	8.132	263.23	306.39	186.63	75.12	0.322	0.905	1.419	6.188	844.38	13.460	2.229
Midlothian, screened - -	4132.00	86.22	6.239	8.001	285.65	297.78	216.95	70.63	0.179	1.289	1.425	6.283	632.10	10.113	1.674
Midlothian, (navy yard) - -	1463.50														

SYNOPTICAL TABLE CLIV—Continued.

Designation of coals.	Evaporation.						Residue from furnace.				Lead reduced from litharge.	
	Steam, in pounds, corrected for temperature of water in cistern, to				Effect of open air plate: (+*gain*, —*loss*.)							
	One of fuel, from initial temperature.	One of fuel, from 212°.	One cubic foot of fuel, from 212°.	One of combustible matter, from 212°.	On economy of fuel, per cent.	On rapidity of evaporation, per cent.	Total of clinker and ashes, from 100 of fuel.	Clinker alone, from 100 of fuel.	Ratio of clinker to total waste.	Pounds of unburnt coke, after each trial.	By one of fuel.	By one of combustible matter.
Barr's Deep Run - - -	7.845	9.018	478.74	10.142	— 5.056	— 7.584	11.073	4.748	0.4288	6.400	24.620	28.007
Crouch & Snead's - - -	7 298	8.345	445.02	9.740	+ 2.990	— 6.802	14.340	5.371	0.3752	6.000	19.617	25.775
Midlothian (900 ft. shaft) average coal	7.499	8.584	433.73	9.611	— 2.613	+ 6.634	10.702	6.466	0.6045	5.917	25.036	26.993
Creek Company's coal - -	7.444	8.417	391.85	9.211	+15,017	+32.179	8.641	4.415	0.4984	10.530	28.100	30.523
Clover Hill - - -	6.713	7.675	347.44	8.588	— 6.633	—25.979	10.601	3.859	0.3580	11.512	26.962	28.527
Chesterfield Mining Company -	7.949	8.998	410.89	9.896	+ 1.623	— 1.895	9.069	4.189	0.4628	10.469	25.784	27.376
Midlothian, average - -	7.303	8.295	448.46	9.741	+ 0.152	—21.610	14.827	8.821	0.5954	6.442	27.344	29.027
Tippecanoe - - -	6.743	7.748	350.23	8.583	+ 7.994	+11.345	9.723	4.034	0.4150	11.250	27.958	29.170
Midlothian, "new shaft" - -	7.665	8.750	418.61	9.751	+ 2,653	+ 6.217	10.258	4.214	0.4218	17.083	25.084	26.797
Midlothian, screened -	7.836	8.944	408.72	9.970	+ 3.471	+ 0.190	10.271	3.329	0.3242	14.800	27,285	29.745
Midlothian, (navy yard) - -	-	-	-	-	-	-	20.100	4.424	-	43.250	25.130	27.230

on the synoptical table of Virginia coals.

he evaporative and the reductive powers of this class ation of the fixed to the volatile portion of their respecters, will still further illustrate the subject of M. Berermining the heating power of fuel.

f coal.	Steam to 1 of combustible.	Lead reduced, to 1 of combustible.	Ratio of fixed to volatile combustible.
- -	10.142	28.007	3.435
ned) - -	9.970	29.745	1.567
ng Company's	9.896	27.376	1.917
shaft) -	9.751	26.797	1.684
ge) - -	9.741	29.027	1.780
- -	9.740	25.775	2.499
eet shaft) -	9.611	26.993	2.239
- -	9.211	30.523	2.032
- -	8.583	28.527	1.793
- -	8.583	29.170	1.599
- -	9.523	28.194	2.054

five, in the second column of numbers, is 28.19; 98. The order of practical evaporative powers is ...ed by the weights of lead reduced by the several specimens of coal.—See table on page 307.

A series of coals, in which the relation of the fixed to the volatile combustible matter is nearly the same as above, was analyzed by M. Baudin, (as found in his paper in the *Annales des Mines*, 4ème série, p. 85,) and the lead reduced by 1 of the combustible matter of each coal was also determined as follows:

Names or localities.	Lead reduced to 1 of combustible.	Ratio of fixed to volatile combustible.
Montes, (Allier) - - - - -	30.98	3.036
Gabelliers - - - - -	31.16	2.987
Megecoste, (Brassac) - - -	30.31	2.704
Langeac - - - - -	30.32	2.575
Champlaix, Haute Dordogne - -	29.62	1.947
Madier - - - - -	29.55	1.945
Les Barthes, (Brassac) - - -	30.58	1.903
Singles, Guignette - - - -	29.74	1.868
Noyant - - - - -	28.19	1.746
Ammenat, (Commentry) - - -	28.64	1.500
Néris - - - - -	27.08	1.431
Bert, (Allier) - - - -	27.04	1.409
La Roche, (Puy-de-Dome) - - -	26.16	1.358
Mean - - - -	29.18	2.032

CLASS IV.

FOREIGN BITUMINOUS COALS, AND THOSE OF SIMILAR CONSTITUTION WEST OF THE ALLEGHENY MOUNTAINS.—PINE WOOD.

SAMPLES.

Foreign coals.

No. 1. Pictou, (purchased in New York.)
2. Sidney.
3. Pictou, (Cunard's.)
4. Liverpool.
5. Newcastle.
6. Scotch.

Coals from west of the Allegheny mountains.

7. Pittsburg.
8. Cannelton, (Ia.)

9. *Dry pine wood.*

General characters.

In many respects, this class of coals bears a strong analogy to the preceding. The ratio of the fixed to the volatile combustible matter, is, however, something less. The exterior presents often a resinous lustre. The surfaces of deposition are easily developed by fracture. Great facility of ignition, and a high degree of activity in the combustion of their volatile constituents, are also general properties of this class. Their high proportion of volatile combustible matter renders these coals, when nearly free from sulphur, eminently suitable for the production of illuminating gas; and the tendency of their cokes, with few exceptions, to intumesce strongly, renders them, in common with the preceding class, highly serviceable in forming large hollow fires for smithing purposes.

No. 1.

Bituminous coal from Pictou, Nova Scotia, procured from Messrs. Laing & Randolph, in New York, for comparative experiments.

This coal has a glimmering lustre, or a dull aspect, according to the part observed. The surfaces of deposition are, in some specimens, inclined in an angle of 83° to the main partings; thin scales of earthy matter are occasionally found in the joints, or vertical seams; but, in general, little impurity is observable on the exterior. Conchoidal fractures are of unfrequent occurrence. The coal was of average size, lumps and fine being intermixed in due proportion, to constitute a merchantable article for ordinary use in smiths' fires and for domestic purposes. The powder of this coal is of a dark brown color, and its streak on a white earthen ground is of the same tint.

The specific gravity of one specimen (*a*) was 1.3546; that of another, (*b*,) 1.2807: from the mean of which, the calculated weight per cubic foot is 82.35 pounds.

By 39 trials in the charge box, the greatest weight of any one charge was 112.25 pounds, or 56.125 pounds per cubic foot. The least weight was 97.5 pounds per charge, or 48.75 pounds per cubic foot; while the average of the whole was 53.548, or 0.6502 of the above calculated weight. The space for the stowage of one ton of the coal is 41.832 cubic feet.

The moisture in specimen *a* was 0.97; and that in *b*, 0.935 per cent.

The volatile matter, other than moisture, in *a*, was 27.51; the sulphur, 0.7689 per cent.

The volatile matter, other than moisture in *b*, was 20.105.

Four incinerations of *a* gave of *ashes* 2.38; and the same number of *b*, 2.65 per cent.

Hence the composition is as follows, viz:

	Specimen *a*.	Specimen *b*.
Moisture - - - -	0.970	0.935
Sulphur - - - - -	0.769	(not tried.)
Other volatile matter - -	26.741	20.105
Earthy matter - - -	2.380	2.650
Fixed carbon - - -	69.140	76.310
	100.	100.
The volatile to fixed combustible	1 : 2.5132	1 : 3.7955

Two specimens of this sample of coal were assayed by Dr. King, and yielded the one 36, and the other 33 per cent. of volatile matter, including moisture. These, combined with the above, give a mean of 29.63, which may probably be assumed as a pretty near approximation to the average yield of this ingredient.

By exposure for four days in the steam drying apparatus, 28 pounds of this coal lost 0.71875 pound of moisture, or 2.567 per cent.

During the four trials of evaporative power, 4153.875 pounds were burned, and yielded 302.4 pounds of ashes, (including those of 408.62 pounds of pine wood,) 253.475 pounds of clinker, and 19.5 pounds of soot.

The ashes lost by reincineration 5.907, and the soot 65.42 per cent. of their weight.

Hence the absolutely incombustible materials are—

From the ashes	284.540	pounds.
From the clinker	253.475	"
From the soot	6.743	"
Total	544.758	"
Deduct for wood ashes	1.227	"
Leaves	543.531	"

which is 13.389 per cent of the coal burned.

By these data we may assign the following as the proximate constituents of this sample, viz:

Moisture (from 28 pounds)	2.567	per cent.
Other volatile matter (mean of four specimens)	27.093	"
Earthy matter (from 4,153.87 pounds)	13.389	"
Fixed carbon	56.981	"
	100.	
Volatile to fixed combustible	1 : 2.1054	

The above result, in earthy matter, derived from a sample of two tons, exhibits a striking contrast with the analyses of single hand specimens.

The clinker is of a dark reddish-brown color, in sheets of considerable magnitude, somewhat porous; small shaly fragments are intermixed, and sometimes adhere to the vitrified masses. It weighed 43.12 pounds per cubic foot, and gained weight by calcination equal to 0.84 per cent., leaving the powder of a light brown, with its finer parts bright red.

The weight of the ashes, as they came from the furnace, was 38.56 pounds per cubic foot; and the residue of their reincineration had a color nearly flesh red, while that from the soot was reddish gray—a shade lighter than that from the ashes.

The ashes from specimens *a* and *b* are of a purplish-red color, with specks of white.

Tried with the oxide of lead, 20 grains of specimen *a* gave 544.8 grains of metallic lead, or 27.24 times its weight. Deducting moisture and earthy matter, this gives to one of combustible matter 28.184.

In a smith's fire, for ordinary work, this coal afforded a rather dull combustion; made a good hollow fire; left a fair coke, not unusually hard; produced a large quantity of cinder, and gave a tolerably fair heat.

In the chain shop, it gave a heavy flame; formed a coke too hard to be easily broken up, as the work requires; was rather hard and unmanageable, and left a large proportion of cinder. Sixty pounds made but 11 links of a chain $1\frac{3}{8}$ inch in diameter; while several other coals, tried by the same workman on the same chain, were found adequate to the making of from 13 to 20 links, by the same weight of coal.

In grates for domestic use, this coal burns with nearly the same characters as are found in the Virginia coals above described. In heating power, it is exceeded by several of that class. The Clover Hill and Tippeca-

hese samples are the only ones of the Virginia series which fall decidedly below it; and if those be included with the rest of the ten samples from Virginia, the average heating power is a little above that of the sample now under consideration. The ten Virginia coals gave of water evaporated from 212° to 1 of coal, 8.4777, and the Pictou, 8.4117.

The ignition of this coal is easily effected. It took, on an average of four trials, only 0.937 hour, or 56¼ minutes, to bring the boiler to a state of steady action. In conformity with this fact is that relative to the unburnt coke, which was, on an average, only 5.689 pounds at each trial.

TABLE CLV.—PICTOU

First trial—upper damper 8 inches open; air plates open;

Period of steady action, from 10*h*. 40*m*. a. m. to 5*h*. p. m.—6*h*. 20*m*.; coal supplied to grate, 764.5 lbs.; water to boiler, 5,588 lbs.; water to 1 of coal, for the same time, 7.301.

COAL (FROM NEW YORK.)

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	76.0	117	—29	-	Wind NE., light; cloudy; commenced firing.
9.35	76.7	90	+ 3	-	Wood consumed, 115 lbs.; commenced charging with coal.
-	76.4	91	21	-	Steam blows off.
-	76.4	93	31	0.683	Air plates opened; damper set at 8 inches.
-	76.1	96	61	1.791	
10.40	74.4	91	64	2.252	Commenced drawing gases from lower flue at 11*h.* 1*m.* a. m.; drew in 34.5 minutes 100 cubic inches, which gave water 1.18 grain, carbonic acid 5.34 grains, oxygen 9.454 cubic inches.
11.27	75.5	108	-	2.129	
0.00	73.8	121	67	2.707	
-	73.8	140	74	2.638	Wind SW., brisk; sun shining; smoke 18 seconds to chimney top; syphon 0.31.
1.00	74.6	157	60	2.617	Smoke 21 seconds to chimney top; syphon 0.25; filled tank at 1*h.* 15*m.* p. m.
-	77.2	166	76	1.865	This coal does not produce to-day much smoke from chimney.
-	75.8	180	76	2.193	Wind NW., light; clear.
2.30	76.9	179	66	2.702	
-	76.9	191	53	2.156	
3.20	76.6	194	78	1.706	Clinker removed from grate at 3*h.* 20*m.* p. m.
-	76.6	202	73	2.850	
4.15	77.8	203	96	2.257	Placed 28 lbs. of this coal in drying apparatus.
5.00	77.3	212	76	2.448	Wind SW., light; clear; filled tank at 5*h.* 20*m.* p. m.
-	78.4	222	64	2.622	Air plates closed, and contents of ash pit thrown on grate.
-	77.5	231	64	-	Water left at 0.6 inch above normal level; damper reduced to 4 inches.
-	74.4	146.5	—22	-	Some fire on grate; water 1.6 inch below normal level.
-	75.3	140	—14	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	65.25
Ashes	58.75
Clinker and ashes behind bridge	10.05
	134.05
Deduct wood ashes	0.353
Total waste of coal	133.697
Coke	3.62

TABLE CLVI.—PICTOU

Second trial—upper damper 8 inches open; air-plates closed;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 31	6.18	78	76	218	197	84	210	79	30.11	0.300	7.05	0.15	–	–
	7.18	81	77	196	260	84	226	78.5	30.10	0.520	5.36	0.22	–	111.25
	7.35	82	78	198	280	84	229	79	30.10	0.527	5.30	0.28	–	–
	8.00	82	77	198	308	84	229	79	30.10	0.529	5.28	0.30	96	105.00
	8.30	84	78	197	322	84	229	80	30.10	0.543	5.14	0.30	354	–
	9.00	86	79	202	370	84	231	82	30.10	0.565	5.02	0.45	604	–
	9.30	87	79	210	330	82	230	84	30.10	0.543	5.14	0.38	1314	97.50
	10.00	88	80	223	346	82	230	85	30.10	0.543	5.14	0.38	1638	109.75
	10.30	90	81	237	322	82	229	86	30.10	0.539	5.18	0.30	2212	–
	11.00	91	80	246	372	83	230	86	30.10	0.553	5.04	0.42	2622	–
	11.35	94	81	262	392	88	229	87	30.10	0.528	5.29	0.30	3256	106.75
	P. M.													
	0.00	94	81	268	348	82	229	88	30.09	0.533	5.24	0.30	3506	–
	0.30	96	81	280	343	82	229	89	30.09	0.529	5.28	0.30	4148	108.00
	1.00	97	81	286	328	88	229	89	30.09	0.523	5.34	0.30	4658	108.25
	1.30	97.5	81	302	334	83	230	90	30.06	0.529	5.28	0.30	5075	–
	2.00	98	81	304	300	83	229	90	30.04	0.522	5.35	0.28	5329	110.50
	2.30	98	82	305	–	84	230	91	30.04	0.545	5.12	0.30	5934	–
	3.00	99	85	304	332	84	230	92	30.03	0.537	5.20	0.28	6268	111.25
	3.35	100	84	316	322	84	229	93	30.03	0.525	5.32	0.26	6778	103.50
	4.00	99	84.5	326	350	84	229	92	30.05	0.523	5.34	0.32	7090	–
	4.30	98	82	340	288	84	228	92	30.05	0.515	5.41	0.22	7480	–
	5.00	96	81	342	280	86	228	91	30.05	0.505	5.52	0.20	7780	–
	A. M.													
Sept. 1	5.30	81	76	220	200	86	216	81	30.07	0.397	6.58	0.15	–	–
	6.15	82	77	212	193	85	212	81	30.08	0.350	7.06	0.18	8340	–

Period of steady action, from 9*h.* 15*m.* a. m. to 3*h.* 35*m.* p. m. = 6*h.* 20*m.*; coal supplied to grate, 758 lbs ; water to boiler, 5,756 lbs ; water to 1 of coal, 7.593.

COAL (FROM NEW YORK.)

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	75.3	140	—18	-	Commenced firing; morning foggy; wind W.; water 0.1 inch above normal level.
7.18	75.6	115	+94	-	Wood consumed, 103.5 lbs.; commenced charging with coal.
-	76.7	116	51	-	Steam blows off; sun shining.
7.45	75.3	116	79	0.610	Damper reduced to 8 inches.
-	76.1	113	93	1.102	
-	76.9	116	139	-	Filling tank; water in boiler 0.4 inch below normal level.
9.15	76.6	123	100	2.453	Tank filled at 9*h.* 15*m*.
10.05	77.7	135	116	1.716	
-	78.6	147	103	3.041	
-	76.9	157	142	2.172	Smoke 17.5 seconds in reaching chimney top; syphon 0.35.
11.11	77.5	168	103	2.879	Tank partly filled at 11*h.* 40*m*.
-	77.5	174	119	1.589	
0.00	77.1	184	114	3.401	
0.55	76.8	191	99	2.702	
-	76.7	204.5	104	2.209	Commenced drawing gases at 1*h.* 52*m.* from lower flue; drew in 51 minutes 100 cubic inches, which gave water 1.31 grain, carbonic acid 5.69 grains, oxygen 9.798 cubic inches.
1.50	76.6	206	71	1.346	
-	78.0	207	-	3.205	
2.45	81.8	205	102	1.769	Wind W., brisk; clear; dew point, by observation, 76°; by calculation, at same place, 78°.9; clinker removed from grate.
3.35	80.3	218	93	2.596	
-	81.1	227	121	1.759	Contents of ash pit thrown on grate; damper reduced to 4 inches.
-	78.0	242	60	2.066	Filled tank at 4*h.* 45*m*.
-	77.1	246	54	-	Water in boiler left at 0.7 inch above normal level.
-	74.2	139	—16	-	Water found 1.05 inch below normal level.
-	75.3	130	—19	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	66.50
Ashes - - - - - - - - - -	61.25
Clinker behind bridge - - - - - - - - -	0.161
Ashes behind bridge - - - - - - - - -	10.75
	138.661
Deduct wood ashes - - - - - - - - -	0.365
Total waste from coal - - - - - - - - -	138.296
Coke - - - - - - - - - - -	2.255

TABLE CLVII.—PICTOU

Third trial—upper damper 4 inches open; air

									meter.	Height of barometer.				plied to boiler.	Weight of charges of coal.
Sept. 1	6.15	82	77	212	198	85	212	81	30.08	0.350	7.06	0.18	–	–
	6.57	83	77	[illegible]	[illegible]	[illegible]	227	81	[illegible]	[illegible]	5.36	0.23	–	103.50
	7.15	83	[illegible]	201	300	86	232	81	30.09	[illegible]	5.19	0.32	–	–
	7.45	84	77	204	306	86	232	81	30.09	[illegible]	5.12	0.35	300	107.00
	8.30	85	77	213	[illegible]	84	231	81	30.09	0.544	5.13	0.32	909	–
	9.00	86	78	230	320	85	231	82	30.09	0.538	5.19	0.32	1350	112.00
	[illegible]	86	78	245	325	85	[illegible]	[illegible]	30.09	[illegible]	5.20	0.30	1510	–
	10.05	88	79	263	310	82	[illegible]	[illegible]	30.10	0.538	5.24	0.25	2132	106.50
	10.35	88	79	271	300	82	230	85	30.10	0.533	5.24	0.25	2605	–
	11.00	89	80	275	[illegible]	82	231	85	30.10	0.536	5.22	0.29	2958	–
	11.35	90	80	280	310	82	231	86	30.10	0.531	5.26	0.25	3192	105.25
	P. M.													
	0.00	90	79	283	304	82	231	86	[illegible]	[illegible]	5.26	0.25	3440	–
	0.30	91	79	286	311	82	231	87	[illegible]	[illegible]	[illegible]	[illegible]	3700	102.50
	1.00	93	79	296	–	83	231	87	[illegible]	0.539	5.16	[illegible]	4128	110.75
	1.30	95	79	302	312	83	231	88	[illegible]	0.533	5.24	[illegible]	4550	–
	2.00	94	78	304	320	84	231	88	30.06	0.527	[illegible]	[illegible]	4863	–
	[illegible]	95	80	312	312	85	[illegible]	88	30.06	0.527	5.30	0.25	5325	108.00
	[illegible]	95	82	[illegible]	328	85	231	89	30.06	0.531	5.26	0.28	5458	107.25
	[illegible]	94	81	323	[illegible]	[illegible]	231	89	30.06	0.531	5.26	0.30	6124	–
	[illegible]	91	80	328	320	85	231	88	30.06	[illegible]	5.22	[illegible]	6276	–
	4.30	94	81	326	330	85	231	88	[illegible]	[illegible]	5.28	0.28	6721	108.00
	5.00	94	81	334	–	86	231	87	[illegible]	0.541	5.16	0.33	[illegible]	–
	5.30	92	80	338	[illegible]	85	230	86	30.07	0.533	5.24	0.30	7361	108.75
	6.00	90	79	334	313	85	231	[illegible]	30.07	[illegible]	5.28	0.28	7708	–
	6.15	[illegible]	80	336	315	85	230	[illegible]	30.07	0.517	5.40	0.25	[illegible]	–
	A. M.													
Sept. 2	5.35	78	74	260	212	[illegible]	222	79	30.10	0.457	[illegible]	0.12	8163	–
	6.12	81	75.5	242	211	84	218	[illegible]	30.10	[illegible]	[illegible]	0.12	8743	–

Period of steady action, from 7*h.* 35*m.* a. m. to 5*h.* 35*m.* p. m. = 10*h.*; coal supplied to grate, 969 lbs.; water to boiler, 7,219 lbs.; and water to 1 of coal, 7.449

COAL (FROM NEW YORK.)

plates open; steam escaping from both valves.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	75.3	130	—19	-	Wind SW., light; commenced firing; fire in small furnace.
6.57	75.0	116	+65	-	Wood consumed, 107¼ lbs.; commenced charging with coal; coal ignites readily; steam escapes at 7*h.* 12*m.* a. m.; damper
	......	....			
-	74.3	118	68		then set at 4 inches.
7.35	74.7	120	74	1.589	Tank partly filled at 7*h.* 57*m.* a. m.
....			....	....	
-	74.4	128	87	2.151	
8.40	75.5	144	89	1.806	
-	75.5	159	95	1.377	Wind E.; cloudy; filling tank; water 0.3 inch below normal level.
9.50	76.3	175	79	2.821	Filled tank at 9*h.* 45*m.* a. m.
-	76.3	183	70	2.506	Wind NE.
-	77.4	186	82	1.609	
11.09	77.2	190	79	1.517	
-	75.8	193	73	1.683	
0.30	75.5	197	80	1.377	Clinker removed from grate; smoke 23.5 seconds in reaching chimney top; syphon 0.24.
1.12	75.0	203	-	2.267	Commenced drawing gases at 0*h.* 52*m.* p. m. from lower flue; drew in 41.5 minutes 100 cubic inches, which gave of water 1.31 grain, carbonic acid 5.11 grains, oxygen 11.25 cubic inches. The drawing was interrupted at 1*h.* 13*m.* p. m.,
-	74.5	197	81	2.236	and recommenced at 4*h.* 51*m.* p. m. A moderate volume
-	73.3	210	99	1.669	of dark brown smoke from chimney at charging and stok-
2.15	75.9	218	81	2.437	ing.
3.00	78.7	221	97	0.705	Filling tank; water 0.3 inch below normal level; wind SE., light.
-	77.5	229	99	2.646	Filled tank at 3*h.* 5*m.* p. m.; wind strong, increasing.
-	76.9	237	89	2.003	
4.40	77.5	232	99	1.298	
-	77.5	240	-	2.193	Lower damper open; drawing gases (as above;) wind SW.,
5.35	76.6	246	83	1.727	light.
....	....	....	....		
-	75.8	244	82	1.838	
				....	
-	76.9	245	85	-	Air plates closed; contents of ash pit on grate; water 1.01 inch below normal level.
-	72.5	182	—10		
-	73.5	161	— 7	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	61.00
Clinker behind bridge - - - - - - - - -	0.168
Ashes - - - - - - - - - - -	81.25
Ashes behind bridge - - - - - - - - - -	11.85
Total clinker and ashes - - - - - - - - -	154.268
Deduct wood ashes - - - - - - - - - -	0.329
Total waste of coal - - - - - - - - -	153.939
Coke - - - - - - - - - - -	12.89

TABLE CLVIII.—PICTOU

Fourth trial—upper damper 4 inches open; air

Date.	Hour.	Temperatures of the — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 2	6.12	81	75.5	242	211	84	218	78	30.10	0.395	6.62	0.12	-	-
	6.50	82	76	232	280	85	228	79	30.11	0.540	5.17	0.23	-	105.00
	7.10	82	76	229	312	85	228	79	30.12	0.535	5.22	0.30	-	104.25
	7.50	86	77	235	308	82	228	80	30.12	0.527	5.30	0.23	538	-
	8.30	85	77	253	312	82	228	80	30.12	0.537	5.20	0.25	1062	105.50
	9.00	85	77	270	303	82	228	80	30.12	0.540	5.17	0.25	1375	-
	9.30	86	77	277	320	82	228	81	30.12	0.540	5 17	0.25	1803	105.25
	10.00	87	77	286	320	82	228	81	30.12	0.540	5.17	0.24	2051	-
	10.30	88	78	292	313	82	229	82	30.12	0.535	5.22	0.22	2384	-
	11.00	90	79	302	310	82	230	82	30.12	0.531	5.26	0.24	2788	106.25
	11.30	90	79	310	300	82	230	83	30.10	0.542	5.15	0.28	3041	-
	P. M. 0.00	91	80	314	290	82	229	84	30.09	0.525	5.32	0.25	3441	106.75
	0.30	95	80.5	320	320	82	229	85	30.09	0.533	5.24	0.26	3778	-
	1.00	93	80	316	-	83	230	86	30.09	0.536	5.21	0.29	4124	106.75
	1.30	94	80.5	310	290	84	230	87	30.08	0.529	5.28	0.23	4461	104.50
	2.00	96	82	326	296	84	227	87	30.08	0.517	5.40	0.23	4856	-
	2.30	99	83	342	300	84	227	88	30 07	0.517	5.40	0.20	5106	101.75
	3.00	100	83	344	310	83	227	88	30.06	0.517	5.40	0.20	5526	-
	3.30	95	81	360	282	84	226	88	30.06	0.506	5.50	0.20	6101	-
Sept. 3	A. M. 6.50	84	76	258	200	84	215	82	30.02	0.410	6.46	0.12	6114	-
	7.15	84	76	251	206	84	213	83	30.02	0.364	6.92	0.12	6661	-

Period of steady action, from 7*h*. 10*m*. a. m. to 2*h*. 15*m*. p. m. = 7*h*. 5*m*.; coal to grate for that period, 736.75 lbs.; water to boiler for the same time, 4,849 lbs.; water to one of coal, 6.580.

COAL (FROM NEW YORK.)

plates closed; steam escaping from both valves.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	73.5	161	— 7	-	Commenced firing; morning cloudy; wind SW., light; water 0.15 inch above normal level.
6.50	73.9	150	+52	-	Wood consumed, 84 pounds; commenced charging with coal; steam blows off at 6*h.* 57*m.*
7.10	73.9	147	84	-	Upper damper reduced to 4 inches.
-	74.1	149	80	1.613	Filled tank at 7*h.* 40*m.*
8.20	74.4	168	84	2.082	
-	74.4	185	75	1.658	
9.30	74.1	191	92	2.268	
-	73.8	199	92	1.814	
-	74.9	204	84	1.764	Coal in drying apparatus weighs 27 pounds 5½ ounces.
10.40	75.8	212	80	2.140	
-	75.8	220	70	1.348	Smoke 26.5 seconds in reaching chimney top; syphon 0.26.
11.45	76.9	223	61	2.135	Smoke (through lower damper) 12.5 seconds in reaching chimney top; syphon 0.84.
-	76.6	225	91	1.769	Commenced drawing gases through lower flue at 0*h.* 43*m.*;
0.40	76.4	223	-	1.833	drew in 44 minutes 100 cubic inches, which gave water 1.32 grain, carbonic acid 5.63 grains.
1.35	76.8	216	60	1.785	Filled tank at 1*h.* 8*m.*
-	78.4	230	69	2.093	
2.15	79.2	243	73	1.324	Wind SW., clear.
-	78.9	244	83	2.225	Contents of ash pit on grate; dew point, by observation, 74°; by calculation, 75°.8.
-	77.3	265	56	-	Water in boiler at 1.3 inch above normal level.
-	73.3	174	—15	-	Water in boiler found at 1.67 inch below normal level.
-	73.3	167	— 7	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	60.000
Clinker behind bridge	0.146
Ashes	59.250
Ashes behind bridge	9.500
	128.896
Deduct wood ashes	0.257
Total waste from coal	128.639
Coke	4.11
Soot	19.50

TABLE CLIX.—DEDUCTIONS FROM

Experiments on Pictou

	Nature of the data furnished by the respective tables.	1st Trial. (*Table CLV.*)	2d Trial. (*Tab. CLVI.*)
		August 30.	*August* 31.
1	Total duration of the experiment, in hours	22.033	23.95
2	Duration of steady action, in hours	6.333	6.333
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	9.0	10.0
7	Total weight of coal supplied to grate, in pounds	978.50	1071.75
8	Pounds of coal actually consumed	974.88	1069.612
9	Pounds of coal withdrawn and separated after trial,	3.62	2.138
10	Mean weight, in pounds, of one cubic foot of coal	54.361	53.5875
11	Pounds of coal supplied per hour, during steady action	120.77	119.69
12	Pounds of coal per square foot of grate surface, per hour	8.583	8.506
13	Total waste, ashes and clinker, from 100 pounds of coal	13.714	12.934
14	Pounds of clinker alone, from 100 pounds of coal	6.6911	6.2139
15	Ratio of clinker to the total waste, per cent.	48.788	48.0695
16	Total pounds of water supplied to the boiler	7759.0	8340.0
17	Mean temperature of water, in degrees Fahrenheit	82°.8	83°.0
18	Pounds of water supplied at the end of experiment, to restore level	782.0	550.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	99.0	69.0
20	Pounds of water evaporated per hour, during steady action	882.36	908.88
21	Cubic feet of water per hour, during steady action	14.12	14.54
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.337	2.407
23	Pounds of water per square foot, by a mean of several observations	2.347	2.397
24	Water evaporated by 1 of coal, from intial temp. (a) final result	7.858	7.733
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	7.301	7.5936
26	Pounds of fuel evaporating one cubic foot of water	7.9537	8.0823
27	Mean temperature of air entering below ash pit, during steady pressure	92°.31	92°.59
28	Mean temp. of wet bulb thermom., during steady pressure	79°.08	80°.69
29	Mean temperature of air, on arriving at the grate	254°.92	259°.125
30	Mean temperature of gases, when arriving at the chimney	301°.25	334°.6
31	Mean temperature of steam in the boiler	229°.54	229°.5
32	Mean temperature of attached thermometer	84°.88	86°.94
33	Mean height of barometer, in inches	30.161	30.079
34	Mean number of volumes of air in manometer	5.225	5.210
35	Mean height of mercury in manometer, in atmospheres	0.5342	0.5366
36	Mean height of water in syphon draught gauge, in inches	0.2907	0.3077
37.	Mean temperature of dew point, by calculation	75°.9	77°.525
38	Mean gain of temperature by the air, before reaching grate	162°.61	166°.535
39	Mean difference between steam and escaping gases	71°.71	105°.1
40	Water to 1 of coal, corrected for temperature of water in cistern	7.8258	7.7013
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	8.8059	8.6658
42	Pounds of water, from 212°, to 1 cubic foot of coal	478.74	464.38
43	Water, from 212°, to 1 pound of combustible matter of the fuel	10.2055	9.9532
44	Mean pressure, in atmospheres, above a vacuum	1.4213	1.4288
45	Mean pressure, in pounds per square inch, above atmosphere	6.2219	6.3324
46	Condition of the air plates at the furnace bridge	Open.	Closed.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

TABLES CLV, CLVI, CLVII, CLVIII.

coal (from New York.)

3d Trial. (*T. CLVII.*)	4th Trial. (*T. CLVIII.*)	Averages.	Remarks.
September 1.	*September* 2.		
23.95	23.05		
10.00	7.083		
14.07	14.07		
377.5	377.5		
18.75	18.75		
11.0	9.0		
1179.5	947.0		
1166.61	942.89		
12.89	4.11	5.6895	
53.614	52.611	53.5434	
96.9	104.01	110.342	
6.887	7.892	7.842	
13.195	13.642	13.3712	
5.2321	6.3657	6.1257	
39.651	46.658	45.7916	
8743.0	6661.0		
84°.1	82°.7		
575.0	547.0		
72.0	69.0		
721.9	684.59	799.432	
11.55	10.953	12.7908	
1.912	1.813	2.1172	
1.893	1.794		
7.482	7.009	7.608	With damper drawn 8 inches, the first trial gave, with a clean surface of boiler and flues, and the air plate open, 7.858 of water to one of coal; the second, with the same plate closed, and surfaces with one day's impurity on the flues, 7.733, or 1.6 per cent. less.
7.449	6.5802	7.231	
8.4096	8.9171	8.3407	
90°.33	69°.8		
79°.21	78°.87		
282°.05	278°.8	268°.724	
315°.42	306°.71	308°.702	
231°.0	228°.6		
85°.71	83°.0		
30.080	30.104		
5.227	5.247		
0.5343	0.5323		
0.2845	0.2443	0.2818	
75°.53	75°.7		
191°.72	189°.0	177°.466	
85°.33	77°.77	84°.69	
7.4609	6.9803	7.4771	
8.3207	7.8545	8.4117	
446.10	413.23	450.612	
9.5856	9.0953	9.7099	In the fourth trial, the decided inferiority of effect to the preceding is probably to be ascribed to the coating of soot upon the flues, and the want of sufficient draught to burn completely the products of combustion.
1.4810	1.4122	1.421	
6.231	6.6876	6.2182	
Open.	Closed.		
U. 4	U. 4		

Remarks on the preceding table of deductions.

This sample of coal appears, from the 13th line of the table, to have yielded a rather unusual quantity of clinker. In the *first* and *second* trials, when the combustion was at the mean rate of 120.23 pounds per hour, the mean proportion of clinker was 48.428 per cent. of the total waste, or it was 6.452 per cent. of the coal burned. In the *third* and *fourth* trials, when the rate of combustion was at a mean of 100.45 pounds per hour, the mean proportion of clinker to total waste was 43.154 per cent., or 5.799 per cent. of the coal burned. The order, in the proportion of clinker throughout the four trials, follows that of the rate of combustion. On three of the four days of trial, it was found necessary, in order to sustain the rate of combustion, to remove portions of clinker from the grate before the conclusion of the experiment. The manometer shows (in table CLV) that at 2*h.* 30*m.* p. m., and before the clinker had been removed, the column of mercury was only 0.525 atmosphere in height; while at the commencement of steady action for the day, it had been 0.549. At 3*h.* 20*m.* clinker was removed, and at 3*h.* 30*m.* the column had already risen to 0.539, which height it retained, with little variation, for 2.5 hours. Again: it will be observed that, on the third trial, (table CLVII,) the mercurial column in the manometer had fallen from 0.545, where it stood at 7*h.* 45*m.* a. m., to 0.529 at 0*h.* 30*m.* p. m., at which hour the column of "remarks" shows that "clinker was removed from grate." At 1*h.* 0*m.* p. m. the height of manometer was again up to 0.539. From this, in the course of three hours and a half, it again declined to 0.529. These augmentations of pressure are to be understood as having taken place without varying the weights on the safety valves, and merely in consequence of the more rapid generation of steam, and of the increased quantity seeking exit through the limited annular spaces round the valves.

The period of steady action on each of the first two trials was the same, viz: 6*h.* 20*m.* On the one at which the combustion was conducted with air plate *open*, (August 30,) the evaporation was 14.12 cubic feet of water per hour; with the plate *closed*, (August 31,) the evaporation was 14.54 cubic feet per hour. It does not, however, appear that this greater rapidity of evaporation was attended with a correspondent increase in the economy of fuel, but the reverse; for at lines 40, 41, and 43, the numbers in the column under August 30 are all higher than the corresponding ones in the next column, under August 31. The amount of the difference in the 43d line (*water from* 212° *to* 1 *of combustible matter*) is 0.2523. But it will be remarked that the gases reached the chimney on the second trial at a considerably higher temperature than on the first, the 39th line showing an excess of the escaping gases over the steam, of 71°.7 on the first, and 105°.1 on the second trial. The analyses of dry gases from the chimney show that on the first trial they were equivalent in heat-absorbing power to 18.833, and on the second to 16.934 pounds of air to the pound of *fuel* burned. The water derived from the combustion of a pound of fuel on the first day appears to have been 0.2826 pound, and on the second 0.3416. The heat expended on the dry gases required in the combustion of one

pound of *combustible matter* was adequate to produce 0.1693 pound more of steam on the second day than on the first. The heat employed on the *water of combustion* from one of combustible, was equivalent to producing 0.0972 of steam more on the second than on the first day of trial. The sum of these differences is 0.2665, or a trifle more than the difference in the evaporative power (0.2523) actually observed in the action of the boiler. Errors of observation may easily account for the excess.

No. 2.

Bituminous coal from Sidney, Nova Scotia, sent for trial by Mr. Cunard, agent for the General Mining Association of London.

This coal is of a slaty structure, cleaves easily parallel to the surfaces of deposition, revealing large quantities of carbonaceous clod or mineralized charcoal. The plies of shining coal seen on the surfaces of the main partings are generally very thin. Carbonate of lime occasionally lines the seams of the partings, but not in large amount. The sample was generally in lumps. It shows no great degree of friability, but, on the contrary, requires considerable force to break it. Needle-shaped crystals of sulphate of iron are sometimes found in considerable quantities coating the faces of the coal. When reduced to powder, this coal has a dark-brown color, and the streak it leaves on white porcelain is of the same shade.

The specific gravity of one specimen (*a*) was 1.3473, that of another (*b*) 1.3298; the mean giving the calculated weight 83.66 pounds per cubic foot.

By an average of seventeen trials at the time of burning this sample, the actual weight in the state of lumps was 47.441 pounds per cubic foot, or 0.567 of the calculated weight.

To stow one ton, 47.217 cubic feet of space will be required.

By slow coking, specimen *a* lost 24.51 per cent. of its weight; and by rapid coking, *b* lost 29.36 per cent.

The quantity of earthy matter in *a* was 13.88, and in *b* 11.083 per cent. Hence the proximate constituents are—

	Specimen *a*.	Specimen *b*.
Volatile matter - - - - -	24.51	29.360
Fixed carbon - - - - -	61.61	59.557
Earthy matter - - - - -	13.88	11.083
	100.	100.
Volatile matter to fixed combustible	1 : 2.572	1 : 2.0285

By exposure in the drying apparatus during the experiments on evaporation, 28 pounds lost 14 ounces, or 3.125 per cent. of moisture. There were burned 1,601.125 pounds of this coal during the two trials; and the ashes withdrawn were 61.25, the clinker 36.50, and the soot 6.25 pounds.

After complete reduction of carbonaceous particles,

The *ashes* left	52.905	pounds.
The *clinker*	34.539	"
The *soot*	1.932	"
Total	89.376	"
From which deduct for ashes of 431.75 pounds of wood	1.396	"
Leaves	87.980	pounds

of absolutely incombustible matter in the coal, or 5.495 per cent. Hence, admitting the mean of the two determinations of volatile matter above exhibited to give the average of the sample, we may state the composition from this analysis in the large way as follows, viz:

Moisture (from 28 pounds)	3.125
Other volatile matter (mean of two trials)	23.810
Earthy matter (from 1,601.125 pounds)	5.495
Fixed carbon (by difference)	67.570
	100.

Volatile to fixed combustible=1 : 2.8379.

The ashes from this coal weighed 52.42 pounds per cubic foot, the clinker 40.12, and the soot 3.96 pounds; the last being among the lightest of soots found during the whole series of trials. The volatile and combustible matter of the soot amounted to 69.089 per cent.

The clinker is black, compact, in thin sheets, evidently highly fusible, spreading over and adhering to the grate bars, with some lighter colored shaly matter generally encrusted by the vitreous portion. The fact of its adhesion to the grate was noticed during the combustion, and the constant high temperature of the bars evinced that the iron of which they were composed was undergoing a species of combustion—possibly by the reaction of the bi-sulphuret of iron in the coal yielding a portion of its sulphur to the metal of the bars.

When pulverized and reincinerated, the clinker left a dark-gray powder, scarcely tinged with red; the ashes produced a tint of red more distinct than the clinker, but the soot left a residuum of the same color as that from the latter. The earthy matter from the two analyses of hand specimens was almost perfectly white.

Specimen *b*, above referred to, gave, when treated with oxide of lead, 25.007 times its weight in metallic lead. Deducting 11.083 per cent. of the weight of coal for earthy matter, and 3.125 per cent. for moisture, leaves 0.85792 parts of combustible by which to divide the above number of parts of lead; this gives 29.148 parts of lead to 1 of combustible matter of the coal. The only uncertainty in this result is in the proportion of moisture, which, being derived from the trial on 28 pounds, may not improbably be a little too high for the particular specimen under analysis.

The quantity of coal sent in this sample was too small to leave any portion for trial in grates and smith shops, after the two experiments on evaporative power had been completed.

By a comparison of its heating power with that of the preceding and the following samples, (both of which were from Pictou,) it will be seen that

while those two gave of water evaporated by 1 of coal from 212°, 8.4117 and 8.4848, or a mean of 8.4482, this gave but 7.987. The difference, 0.6612, is 7.82 per cent. of the said mean. But as the amount of waste from Pictou coal was, on an average, 12.7168 per cent., while in the *Sidney* coal it was but 6.01, these two numbers being, respectively, deducted from 100, leave the proportions of combustible matter producing the evaporation of the quantities of water above designated; after this deduction, it will be found that the heating power of the *combustible matter* in Pictou coal is represented by 9.679, while that in the Sidney is but 8.497, and the difference is 1.182, or 12.21 per cent. of the first number. This points to a distinct character in the combustible matter of each coal.

The steam from 212° to 1 cubic foot of coal by this sample is 378.92 pounds, while by the mean of the two samples of Pictou coal, it is 434.26; or Sidney is inferior to Pictou by 12.74 per cent.

This coal ignites promptly. In the first trial it was in pretty active combustion in 12 minutes from the time of commencing the charge. It burns rapidly, agglutinates and swells but slightly; its coke falls into small fragments, which facilitates its passage through the grate, and tends to produce waste, unless the interstices be very narrow. It burns with a large and smoky flame, keeping, as already mentioned, the grate bars at a cherry-red heat. The mean time required to bring the boiler into steady action was 1.18 hour, and the mean amount of unburnt coke was 5.9375 pounds. These circumstances indicate great facility in commencing and continuing the combustion.

TABLE CLX.—SIDNEY (N. S.)

First trial—upper damper 8 *inches open ; air plates closed ;*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
Sept. 30	5.40	56	54	136	160	66	179	61	30.19	0.364	6.92	0.10	-	-
	6.45	57	54.5	130	224	66	196	59.5	30.19	0.396	6.50	0.25	-	-
	7.15	57	55	130	234	66	212	59	30.19	0.436	6.20	0.25	-	-
	7.30	58	55	132	228	66	222	59	30.19	0.470	5.85	0.24	-	-
	7.50	58	53	135	230	66	227	59.5	30.19	0.530	5 26	0.24	-	91.75
	8.30	61	57	143	264	66	232	60	30.19	0.557	5.01	0.30	249	101.00
	9.00	63	59	164	279	66	232	60	30.18	0.551	5.07	0.31	654	102.2
	9.30	66	60	199	266	66	232	61	30.19	0.557	5 01	0.32	1159	-
	10.00	67	61	224	280	66	232	62	30.19	0.550	5.08	0.31	1686	92.00
	10.30	68	62	246	298	65	232	63	30.19	0.548	5 10	0.31	2109	92.00
	11.00	70	62	253	320	66	231	64	30.19	0.543	5.14	0.30	2616	92.00
	11.40	71	62	268	298	65	232	66	30.17	0.543	5.14	0.30	3188	91.50
	P. M.													
	0.00	72	62	274	311	65	231	66	30.17	0.543	5.14	0.30	3566	-
	0.35	75	65	283	310	65	231	67	30.17	0.545	5.12	0.31	4074	-
	1.00	77	66	288	317	65	231	68	30.15	0.544	5.13	0.31	4372	97.00
	1.30	76	66	292	318	66	231	68	30.15	0.533	5.24	0.28	4796	-
	2.08	71	63	287	270	66	228	68	30.13	0.517	5.40	0.25	5051	-
	3.15	69	62	286	230	66	227	67	30.12	0.515	5.42	0.20	5139	-
	A. M.													
Oct. 1	6.10	66.5	64.5	188	180	68	210	66.5	29.92	0.353	7.02	0.13	5141	-
	7.00	66	64.5	176	178	68	208	67	29.91	0.353	7.02	0.12	5448	-

Period of steady action, from 8*h*. 58*m*. a. m. to 0*h*. 58*m*. p. m. = 4*h*.; coal supplied to furnace for that time, 464.5 lbs.; water to boiler, same period, 3,696 lbs.; water to 1 of coal, 7.957.
The coal of the lighter charges generally in lumps; the rest mixed, lumps and fine.

COAL, (FROM CUNARD, AGENT.)

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	52.0	80	— 19	-	Commenced firing at 6*h*. a. m.; morning clear and calm.
-	52.0	73	+ 28	-	Water in boiler 0.24 inch below normal level.
-	53.1	73	22	-	Water in boiler 0.10 inch below normal level.
-	52.2	74	6	-	Water at 0.
7.50	47.8	77	3	-	Wood consumed, 209¼ lbs.; commenced charging with coal; damper 8 inches at 8*h*. 7*m*. a. m.; coal in active
8.25	53.6	82	32	0.909	combustion 12 minutes after charging; steam blows off at 8*h*. 5*m*. a. m.; morning has become cloudy.
8.58	55.8	101	47	2.146	
-	55.7	133	34	2.675	Steam escaping from back valve.
9.53	56.9	157	48	2.792	Sprinkling of rain; wind NE., very light.
10.20	58.1	178	66	2.241	
11.27	56.9	183	89	2.686	
11.57	56.2	197	66	2.273	Filled tank at 11*h*. 37*m*. a. m.
-	55.7	202	80	3.004	Not much smoke appears from chimney top from this coal.
-	59.5	208	79	2.307	Commenced drawing gases at 0*h*. 42*m*. p. m.; drew in 20
0.58	60.3	211	86	1.894	minutes 100 cubic inches, which gave water 1.77 grain, carbonic acid 5.74 grains, oxygen 10.928 cubic inches.
-	60.8	216	87	2.247	Fire decreasing rapidly; contents of ash pit thrown on grate.
-	58.1	216	42	1.067	Damper reduced to 4 inches.
-	57.5	217	3	-	Cloudy; wind NE., light; water in boiler at normal level at 8*h*. 15*m*. p. m.; closed damper and air port; found water
-	68.5	121.5	— 30		in the morning (Oct. 1) 0.54 inch below normal level.
-	68.5	110	— 30	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	16.50
Ashes	27.25
Ashes behind bridge	0.70
Total clinker and ashes	44.45
Deduct wood ashes	0.642
Total waste from coal	43.808
Coke	3.625

TABLE CLXI.—SIDNEY (N. S.)

Second trial—upper damper 8 *inches open; air plates open;*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
Oct. 2	6.10	71	63	138	158	70	182	70	29.81	0.349	7.06	0.11	-	-
	7.50	71	63	133	264	70	217	68	29.82	0.447	6.08	0.22	-	-
	8.18	76	66	137	261	70	228	69	29.82	0.529	5.28	0.22	-	89.25
	8.30	74	64	141	253	70	231	69	29.82	0.535	5.22	0.28	-	-
	9.00	74	64	150	283	70	231	71	29.82	0.537	5.20	0.30	137	92.50
	9.30	75	65	164	298	70	231	72	29.82	0.540	5.17	0.30	478	-
	10.00	77	65	181	325	70	232	74	29.82	0.539	5.18	0.31	798	107.00
	10.30	78	66	204	335	70	232	75	29.82	0.539	5.18	0.32	1296	92.25
	11.00	79	67	222	336	70	232	75	29.82	0.543	5.14	0.33	1545	-
	11.30	80	67	243	330	70	231	76	29.82	0.536	5.21	0.31	2033	91.75
	P. M.													
	0.00	82	68	260	334	70	231	76	99.82	0.545	5.12	0.33	2458	-
	0.30	82	68	270	356	70	232	76	29.81	0.539	5.18	0.31	2877	97.50
	1.00	83	69	281	344	70	231	77	29.80	0.536	5.21	0.31	3385	98.00
	1.35	84	69	285	350	70	232	78	29.80	0.543	5.14	0.36	3986	89.00
	2.00	84	69	292	358	70	231	78	29.79	0.540	5.17	0.35	4318	-
	2.30	85	69	305	360	70	232	79	29.78	0.541	5.16	0.31	4655	-
	3.00	86	71	313	345	70	231	79	29.77	0.527	5.30	0.30	4984	96.25
	3.30	86	73	320	300	70	230	79	29.76	0.522	5.35	0.29	5229	-
	4.00	87	75	317	274	71	229	79	29.76	0.506	5.50	0.22	5483	-
	8.00	75	66	292	212	72	229	75	29.77	0.493	5.63	0.15	-	-
	A. M.													
Oct. 3	6.35	67	57	206	186	71	217	66	29.76	0.380	6.76	0.15	-	-
	7.06	67	58	204	183	71	212	65	29.77	0.352	7.03	0.14	5877	-

Period of steady action, from 8*h.* 53*m.* a. m. to 2*h.* 35*m.* p. m.—5*h.* 42*m.*; coal supplied to the furnace, 671.75 lbs.; water supplied to the boiler, 4,614 lbs.; water to 1 of coal for the same time, 6.855.

COAL, (FROM CUNARD, AGENT.)

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					Morning clear; wind NW., light; fire made in small furnace.
-	58.1	67	—24	-	Commenced firing at 6h. 18m.; water 0.37 inch below normal level.
-	58.1	62	+47	-	Water 0.5 inch below normal level.
8.18	60.8	61	33	-	Wood consumed, 222½ lbs.; commenced charging with coal; water 0.2 inch above normal level.
-	58.3	67	22	-	Steam blows off; air plates opened; damper set at 8 inches at 8h. 50m.
8.53	58.3	76	52	0.726	
-	59.5	89	67	1.806	The third charge of coal contains one very large lump.
9.45	58.6	104	93	1.695	Wind W., brisk; clear. Commenced drawing gases at 10h. 23m.; drew in 25 minutes 100 cubic inches; which gave water 0.91 grain, carbonic acid 4.94 grains, oxygen 10.355 cubic inches; filling tank at 11h.; water below normal level.
10.30	59.8	126	103	2.638	
-	61.1	143	104	1.319	
11.19	60.7	163	99	2.585	Filled tank at 11h. 17m.
-	61.5	178	103	2.225	
0.13	61.5	188	124	2.246	
0.57	62.8	198	113	2.824	Placed 28 lbs. of this coal in the drying apparatus.
1.26	62.4	201	118	2.724	
-	62.4	208	127	2.117	
-	62.0	220	128	1.775	This coal produces only a moderate quantity of smoke from chimney; air plates closed, and contents of ash pit thrown on grate.
2.36					
	65.0	227	114	1.743	
-	68.2	234	70	1.298	Damper reduced to 4 inches at 3h. 20m.; filled tank at 3h. 50m.
-	70.9	230	45	1.365	Water in boiler left at 0.15 inch above normal level.
-	61.3	217	—17	-	Finding steam just at equilibrium, double weighted the safety valves.
-	48.8	139	—31	-	The clinker of this coal is solid and heavy, diffusing itself over, and adhering to, the grate; water in boiler adjusted.
-	51.0	137	—29		

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	20.00
Ashes - - - - - - - - - - - -	32.50
Ashes behind bridge - - - - - - - - -	0.86
	53.36
Deduct wood ashes - - - - - - - - -	0.682
Total waste from coal - - - - - - - -	52.678
Coke - - - - - - - - - - - -	8.25
Soot - - - - - - - - - - - -	6.25

TABLE CLXII.—DEDUCTIONS

Experiments on Sidney (Nova

	Nature of the data furnished by the respective tables.	1st Trial. (*Table CLX.*)	2d Trial. (*Table CLXI.*)
		September 30.	*October* 2.
1	Total duration of the experiment, in hours - -	25.333	24.933
2	Duration of steady action, in hours - - -	4.0	5.7
3	Area of grate, in square feet - - - -	14.07	14.07
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	18.75	18.75
6	Number of charges of coal supplied to grate - -	8.0	9.0
7	Total weight of coal supplied to grate, in pounds -	759.5	853.5
8	Pounds of coal actually consumed - - -	755.875	845.25
9	Pounds of coal withdrawn and separated after trial -	3.625	8.25
10	Mean weight, in pounds, of one cubic foot of coal -	47.468	47.417
11	Pounds of coal supplied per hour, during steady action -	116.125	117.85
12	Pounds of coal per square foot of grate surface, per hour -	8.253	8.376
13	Total waste, ashes and clinker, from 100 pounds of coal -	5.795	6.225
14	Pounds of clinker alone, from 100 pounds of coal -	2.1564	2.3342
15	Ratio of clinker to the total waste, per cent. - -	37.208	37.498
16	Total pounds of water supplied to the boiler - -	5448.0	5877.0
17	Mean temperature of water, in degrees Fahrenheit -	65°.8	70°.1
18	Pounds of water supplied at the end of experiment, to restore level - - - - - - -	307.0	390.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds - - - - -	42.0	53.0
20	Pounds of water evaporated per hour, during steady action	924.0	807.89
21	Cubic feet of water per hour, during steady action -	14.79	12.92
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - - -	2.447	2.14
23	Pounds of water per sq. foot, by a mean of several observations	2.446	2.141
24	Water evap. by 1 of coal, from initial temp , (a) final result	7.1518	6.89
25	Water evaporated by 1 of coal, from initial temperature, (b) during steady action - - - - - -	7.957	6.855
26	Pounds of fuel evaporating one cubic foot of water -	8.7391	9.0711
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - -	69°.0	80°.25
28	Mean temp. of wet bulb thermom., during steady pressure	61°.6	67°.17
29	Mean temperature of air, on arriving at the grate -	234°.2	238°.08
30	Mean temperature of gases, when arriving at the chimney	294°.3	334°.08
31	Mean temperature of steam in the boiler - - -	231°.6	231°.5
32	Mean temperature of attached thermometer - -	63°.7	75°.58
33	Mean height of barometer, in inches - - -	30.179	29.81
34	Mean number of volumes of air in manometer - -	5.694	5.171
35	Mean height of mercury in manometer, in atmospheres -	0.5481	0.5398
36	Mean height of water in syphon draught gauge, in inches	0.307	0.32
37	Mean temperature of dew point, by calculation - -	56°.87	60°.87
38	Mean gain of temperature by the air before reaching grate	165°.2	157°.83
39	Mean difference between steam and escaping gases -	68°.2	107°.75
40	Water to 1 of coal, corrected for temp. of water in cistern	7.1399	6.8743
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - -	8.152	7.8231
42	Pounds of water, from 212°, to 1 cubic foot of coal -	386.96	370.9
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	8.6535	8.8418
44	Mean pressure, in atmospheres, above a vacuum - -	1.4228	1.4211
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.2449	6.2197
46	Condition of the air plates at the furnace bridge - -	Closed.	Open.
47	Inches opening of damper, (U. upper) - - -	U. 8	U. 8

FROM TABLES CLX, CLXI.

Scotia) coal, from Cunard, agent.

Averages.	Remarks.
5.9375	
47.4425	
116.987	
8.3145	
6.01	
2.2453	
37.358	
865.945	
13.855	
2.2935	
7.0209	
7.406	
8.9051	
236°.14	
314°.19	The gases appear to have arrived at the chimney, on the second trial, at a temperature 40 degrees higher than on the first.
0.3135	
161°.565	
87°.975	
7.0071	
7.987	
378.93	
8.4974	The efficiency of the pound of combustible matter of this coal was lower in the second than in the first trial by 3.6 per cent.
1.422	
6.2383	

No. 3.

Bituminous coal from Pictou, Nova Scotia, sent by Mr. Cunard, agent of the General Mining Association of London.

The coal of this sample is, in every external character, entirely similar to that from the same mining district obtained from New York. The specific gravity of one specimen (*a*) was 1.3155; that of another, (*b*,) 1.3352. The mean of these makes the weight of the cubic foot in the solid state 82.835 pounds. The actual weight determined by 20 trials in the charge box is for the least 45.5, for the greatest 52.125, and for the average 49.25 pounds per cubic foot, or 0.5945 of the calculated weight. Hence the space to receive one ton is 45.482 cubic feet.

The moisture expelled by thoroughly drying specimen *b* was 1.079.

The coking of *a* caused a loss, including moisture, of 26.413 per cent. The process having been conducted very slowly, the powder did not become agglutinated; but another portion of the same powder, suddenly exposed to a bright red heat, became converted into a well-formed mass. Of specimen *b*, a portion, coked so slowly and at so low a heat that the gas did not take fire, exhibited a loss of 27.1 per cent. Another portion of the same powder, coked rapidly so as to become completely coalescent, lost 29.34 per cent.

The earthy matter in *a* was 10.09, in *b* 11.404 per cent. Hence the proximate constituents of these two specimens are—

	Specimen *a*.		Specimen *b*.	
Moisture -	(not separately determined)		1.079	
Volatile matter - -	26.413	other than moisture	26.021	(by slow coking.)
Earthy matter - -	10.090		11.404	
Fixed carbon - -	63.497		61.496	
	100.		100.	
Volatile to fixed combustible	1 : 2.404		1 : 2.3633	

The moisture expelled from 28 pounds dried in the steaming apparatus, amounted to 0.7812 per cent. The volatile matter, including moisture, from the mean of the two specimens above given, is 26.756.

During the two experiments on evaporation, there were burned 1,962.5 pounds of this coal, and the—

Weight of ashes withdrawn was - -	116.00	pounds.
Weight of clinker - - - - -	121.75	"
Weight of soot - - - - - - -	8.75	"

The ashes lost 0.04077 of their weight, and the soot 0.60144, by reincineration. Reducing the weights of these two, and deducting 1.029 pound for the ashes of 355.25 pounds of pine wood, we have left 245.481 pounds for the total waste from the above weight of coal, or 12.508 per cent.

From these data it would seem that the coal is composed of—

Moisture (from 28 pounds) - - - - -	0.7812
Other volatile matter (from two specimens) - -	25.9753
Earthy matter (from 1,962.5 pounds) - - -	12.5085
Fixed carbon (calculated by difference) - -	60.7350
	100.

Volatile to fixed combustible 1 : 2.5929.

The ashes weighed	39.01	pounds per cubic foot.	
The clinker	" 38.00	"	"
The soot	" 3.82	"	"

When reincinerated or calcined, the clinker became of a dark-drab or light-brown color, the ashes of a light reddish-gray, and the residue of the soot a light-drab color. The ashes from analysis of *a* were pure white; from *b*, dirty white.

The clinker, as it came from the furnace, was black, vitreous, and porous, in masses tolerably friable, and not apparently prone to adhere to the grate. Much shaly matter attaches itself to the vitrified portions.

With the oxide of lead, specimen *b* gave 23.355 times its weight in metallic lead. Deducting moisture and earthy matter, we have left 0.87517 of combustible; by which, dividing the above, we get $\frac{23.355}{.87517}=26.686$.

For the reason assigned in regard to the preceding sample which accompanied this, the trial in smith's forges and in open grates was necessarily dispensed with. This is the less to be regretted in the present instance, as the sample of Pictou coal already described has been tested in the forge; and as the action of the two samples is in other respects almost identical, there is no reason to doubt that in this particular also they would be found to coincide.

The mean time required to bring the boiler to a steady rate of evaporation was 0.85 hour, or 51 minutes. The weight of coke left unburnt on the grate was very small, being on the first trial 5 pounds, and on the second 2.5. The combustion commenced promptly, and the flame was long, and accompanied by considerable smoke. The large amount of clinker (more than 50 per cent. of the total waste) rendered it necessary to remove the heavier masses within a few hours after the fire was kindled.

TABLE CLXIII.—PICTOU (N. S.)

First trial—upper damper* 8 *inches open; air plates closed;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 27	5.20	61	54	136	164	75	180	62	30.10	0.360	6.92	0.10	-	-
	7.30	59.5	52	133	232	75	227	58	30.12	0.525	5.31	0.23	-	102.25
	8.00	59	52	137	250	75	230	59	30.14	0.565	4.92	0.33	-	-
	8.30	60	52	144	286	75	232	59	30.14	0.562	4.95	0.38	492	104.25
	9.00	61	53	152	280	75	232	60	30.14	0.555	5.02	0.36	1295	96.25
	9.30	62	54	162	286	75	232	62	30.13	0.560	4.98	0.37	1818	94.25
	10.00	64	55	175	313	75	231	63	30.14	0.555	5.02	0.36	2311	-
	10.30	64	55	192	312	68	231	64	30.14	0.541	5.16	0.30	3044	96.75
	11.00	66	56	214	297	68	231	64	30.14	0.553	5.04	0.32	3561	103.25
	11.30	65	56	230	314	68	232	64	30.16	0.556	5,01	0.31	4048	101.50
	P. M.													
	0.00	66	56	242	295	68	231	63	30.15	0.555	5.02	0.30	4691	98.25
	0.35	66	56	254	292	68	230	62	30.15	0.556	5.01	0.30	5186	-
	1.00	66	56	262	292	69	230	62	30.15	0.552	5.05	0.30	5683	100.00
	1.30	68	58	274	306	69	231	62.5	30.16	0.554	5.03	0.30	6232	95.50
	2.00	67	57	281	312	69	230	63	30.16	0.546	5.11	0.29	6666	-
	2.30	68	57	288	289	69	230	63	30.16	0.535	5.22	0.21	6879	-
	3.00	68	57	285	268	70	228	63	30.17	0.520	5 37	0.20	7090	-
	3.40	67	56	289	248	70	226	63	30.16	0.515	5.41	0.18	7249	-
	A. M.													
Sept. 28	6.00	50	48	186	184	68	209	55	30.25	0.365	6.90	0.17	7276	-
	6.25	50	48	183	181	68	206	53	30.25	0.370	6.86	0.18	7545	-

Period of steady action, from 8*h*. 14*m*. a. m. to 1*h*. 30*m*. p. m.—5*h*. 16*m*. Coal supplied to grate for that time, 785.75 lbs.; water to boiler for same time, 5,911 lbs.; water to 1 of coal, 7.522.

COAL, (FROM CUNARD, AGENT.)

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calcula-		Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	47.1	75	—10	-	Morning clear; wind light, N.; commenced firing at 6h. 48m. a. m; water 0.4 inch below normal level.
7.30	43.7	73.5	+ 5	-	Wood consumed, 209½ lbs.; commenced charging with coal; valves double weighted.
-	44.3	73	20	-	Steam escapes at 7h. 44m. a. m., on removing extra weight.
8.14	43.2	84	54	[illegible]	
8.52	44.7	91	48	4.264	Steam allowed to escape from back valve at 8h. 45m. a. m.
9.20	46.2	100	64	2.771	
-	46.7	111	82	2.611	Filled tank at 10h. 15m. a. m.
10.03	46.7	128	81	[illegible]	Clinker removed from grate.
10.38	47.3	148	66	2.686	
11.10	46.2	165	82	2.607	
11.52	47.3	176	64	3.407	
-	47.3	188	62	2.248	Filled tank at 0h. 26m. p. m.
0.42	47.3	196	62	3.159	
1.30	50.2	206	75	2.909	
-	48.8	214	82	[illegible]	Contents of ash pit thrown on grate at 2h. 15m. p. m.
-	48.0	220	59	1.126	
-	48.0	217	40	1.118	Filled tank; damper reduced to 4 inches.
-	46.5	222	22	0.632	Water in boiler left at 0.1 inch above normal level.
-	45.2	136	—25	-	Water in boiler 0.7 inch below normal level.
-	45.2	[illegible]	—26	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	57.00
Ashes	55.50
Ashes behind bridge	2.90
	115.40
Deduct wood ashes	0.641
Total waste from coal	114.759
Coke	5.00

TABLE CLXIV.—PICTOU (N. S.)

Second trial—upper damper 8 inches open; air-plates open;

Date.	Hour.
	h. m.
	A. M.
Sept. 28	6.25
	7.10
	7.30
	8.00
	8.30
	9.00
	9.30
	10.00
	10 30
	11.00
	11.35
	P. M.
	0.00
	0.30
	1 00
	1.30
	2.00
	2.30
	3.15
	3.40
	A. M.
Sept. 29	6.22
	6.48

Period of steady action, from 8h. 30m. a. m. to 1h. 50m. p. m.=5h. 20m. Coal supplied to grate for that time, 660.75 lbs.; water to boiler, 4,995.3 lbs.; water to 1 of coal 7.[illegible].

COAL, (FROM CUNARD, AGENT.)

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS:—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	45.2	133	—25	-	Water 0.15 inch below normal level; commenced firing; wind NE., clear.
7.18	43.8	117	+33	-	Wood consumed, 126 lbs.; commenced charging with coal.
-	45.1	115	41	0.940	Air plates opened; steam escapes at 7*h*. 23*m*., at which time coal in brisk combustion.
7.41	45.0	117	65	1.351	
8.30	46.5	123	98	1.976	Steam allowed to escape from back valve at 8*h*. 52*m*.
-	48.1	140	Mean +102.5	2.977	Thermometer showing the temperature of the gases going to chimney broken, and had to be replaced by another.
9.13	49.4	150		2.199	
9.55	48.5	158		2.697	
-	46.7	168		2.946	
10.36	46.5	169		2.278	
-	48.8	179	107	1.467	Wind SW., brisk; clear; two small weights on front valve; clinker removed from grate; new thermometer for escaping gases in place; filled tank at 11*h*. 35*m*.
11.22	51.0	185	111	3.668	
0.08	48.0	194	108	2.215	Clouding up at 0*h*. 50*m*.
1.00	49.5	202	102	2.426	Placed 28 lbs. of this coal in drying apparatus.
-	51.0	206	110	2.670	
1.50	51.7	210	118	1.934	Except the last charge, the coal burned to-day generally in lumps.
-	53.7	216	120	2.156	Air plates closed at 2*h*. 10*m*.
-	52.4	217	79	1.318	Damper reduced to 4 inches; contents of ash pit thrown on grate.
-	53.0	222	42	1.081	Water in boiler left at 0 05 inch below normal level.
-	53.6	152	—23	-	Water found .95 inch below normal level.
-	54.0	141	—25	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	64.75
Ashes	54.75
Ashes behind bridge	2.85
Total clinker and ashes	122.35
Deduct wood ashes	0.387
Total waste from coal	121.963
Coke	2.50
Soot	8.75

TABLE CLXV.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (*Tab. CLXIII.*)	2d Trial. (*Tab CLXIV.*)
		September 27.	*September* 28.
1	Total duration of the experiment, in hours	25.083	24.383
2	Duration of steady action, in hours	5.267	5.333
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	10.0	10.0
7	Total weight of coal supplied to grate, in pounds	992.25	977.75
8	Pounds of coal actually consumed	987.25	975.25
9	Pounds of coal withdrawn and separated after trial	5.0	2.5
10	Mean weight, in pounds, of one cubic foot of coal	49.6125	48.8875
11	Pounds of coal supplied per hour, during steady action	149.212	127.648
12	Pounds of coal per square foot of grate surface, per hour	10.6	9.072
13	Total waste, ashes and clinker, from 100 pounds of coal	11.62	12.505
14	Pounds of clinker alone, from 100 pounds of coal	5.7655	6.6199
15	Ratio of clinker to the total waste, per cent.	49.347	52.935
16	Total pounds of water supplied to the boiler	7545.0	7204.0
17	Mean temperature of water, in degrees Fahrenheit	70°.5	67°.3
18	Pounds of water supplied at the end of experiment, to restore level	270.0	406.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	37.0	57.0
20	Pounds of water evap. per hour, during steady action	1122.86	936.68
21	Cubic feet of water per hour, during steady action	17.96	14.987
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.974	2.481
23	Pounds of water per square foot, by a mean of several observations	2.988	2.498
24	Water evap. by 1 of coal, from initial temp. (a) final result	7.6049	7.328
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	7.522	7.338
26	Pounds of fuel evaporating one cubic foot of water	8.2174	8.529
27	Mean temperature of air entering below ash pit, during steady pressure	64°.15	64°.33
28	Mean temp. of wet bulb thermom., during steady pressure	55°.08	55°.8
29	Mean temperature of air, on arriving at the grate	209°.15	233°.13
30	Mean temperature of gases, when arriving at the chimney	295°.0	330°.0
31	Mean temperature of steam in the boiler	231°.0	232°.0
32	Mean temperature of attached thermometer	62°.115	59°.67
33	Mean height of barometer, in inches	30.146	30.249
34	Mean number of volumes of air in manometer	5.0246	5.004
35	Mean height of mercury in manometer, in atmospheres	.5546	.5572
36	Mean height of water in syphon draught gauge, in inches	.3241	.3525
37	Mean temperature of dew point, by calculation	46°.78	48°.63
38	Mean gain of temp. by the air, before reaching grate	145°.0	168°.8
39	Mean difference between steam and escaping gases	67°.66	107°.06
40	Water to 1 of coal, corrected for temp. of water in cistern	7.5864	7.3148
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	8 6249	8.3446
42	Pounds of water, from 212°, to one cubic foot of coal	427.9	407.94
43	Water, from 212°, to 1 pound of combustible matter of the fuel	9.7589	9.5373
44	Mean pressure, in atmospheres, above a vacuum	1.4389	1.4408
45	Mean pressure, in pounds per sq. inch, above atmosphere	6.4819	6 5104
46	Condition of the air plates at the furnace bridge	Closed.	Open.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

TABLES CLXIII, CLXIV.

Pictou (N. S.) coal, (Cunard, agent.)

Averages.	Remarks.
3.75	In a very close approach to total combustion, as well as in many other of its properties and modes of action, this sample manifests its affinity with the Pictou coal procured in New York.
49.25	
138.43	
9.836	
12.0625	
6.1927	
51.141	
1029.77	
16.4735	The rate of evaporation with air plate open is 16.5 per cent. less rapid than with the plate closed.
2.7275	
7.4664	
7.43	
6.3732	
221°.14	
312°.5	With the air plate open, as in the second trial, the gases going to the chimney had a temperature 35° higher than with the same plate closed, as in the first experiment. The considerable coating of soot on the flues may have helped to keep the gases at their high temperature, and to diminish the evaporative effect, as seen in lines 41 and 43.
.8383	The second trial had the advantage of a stronger draught than the first.
156°.9	
87°.33	
7.4506	
8.4848	
417.92	
9.6461	
1.4398	
6.4962	

No. 4.

Bituminous coal from Liverpool, England, procured from Laing & Randolph, in New York, for comparative experiments.

This coal has well-defined partings, and surfaces of deposition remarkably even, along which fractures very frequently occur. Its main partings I found to be generally from 85° to 87° inclined to the horizontal seams. The lustre is resinous or pitchy in some fractures, and shining in others; while the mineralized charcoal in the horizontal seams gives them, of course, a dull aspect. Few or no exterior indications of impurity are visible. Its powder is of a dark brown color.

The specific gravity of one specimen (*a*) was 1.254; that of another (*b*) 1.2706; the mean of which indicates 78.89 pounds as the weight of one cubic foot. Forty trials in the charge box gave as the maximum 51.5, the minimum 45.75, and the average of the whole 47.878 pounds per cubic foot; which is 0.6069 of the calculated weight.

This average shows that 46.786 cubic feet of space will be required for one gross ton.

The moisture in specimen *a* was 1.758; that in *b* 1.628.

The sulphur in *a* was 0.3762.

When coked very gradually, *a* gave of volatile matter, including moisture, 32.89; and when coked pretty rapidly, *b* gave 36.41 per cent. of the same material. Another comparative trial of the effect of slow and rapid coking was made by coking *a* rapidly, which caused it to lose 41.14 per cent., and *b* slowly, whereby it lost only 33.05. Taking the mean of the trials by the two methods, *a* gives 37.015; *b* gives 34.73.

Two specimens tried by Dr. King, both by rapid coking, gave 40.333 for the first, and 40.625 for the second, or a mean of 40.479 per cent. of volatile matter, including moisture.

By the mean of four incinerations, *a* gave of earthy matter 1.12, and *b* 2.94 per cent.

Hence the composition of these two specimens may be stated as follows

	Specimen *a*.	Specimen *b*.
Moisture - - - - -	1.785	1.628
Sulphur - - - - -	0.376	(not tried.)
Other volatile matter, by mean of rapid and slow coking	34.854	34.730
Earthy matter - - - -	1.120	2.940
Fixed carbon - - - - -	61.865	60.702
	100.	100.
The volatile to the fixed combustible	1 : 1.756	1 : 1.748

Admitting that the moisture in the two samples tried by Dr. King was equal to that derived from the 28 pounds, the combustible portion would be 40.479—0.892=39.587 per cent.

During the trials of its evaporative power, there were burned of this coal 3,786 pounds.

The ashes withdrawn amounted to 120.5, the clinker to 71.75, and the soot to 18.25 pounds.

By reincineration, the *ashes* lost - - - - -	16.93 per cent.
" the *soot* - - - - -	71.69 "

while the clinker gained a little by calcination.

The ashes of 654.74 pounds of wood was 2.01 pounds.

Making the reductions here indicated, the total incombustible matter recovered, and which was derived from the coal alone, was 175 pounds, or 4.622 per cent. From these data, entirely independent of the above analyses of *a* and *b*, we have the composition of the sample as follows:

Moisture, from 28 pounds - - - - -	0.892
Other volatile matter, by two specimens - -	39.587
Earthy matter, from 3,786 pounds - - -	4.622
Fixed carbon, by difference - - - - -	54.899
	100.

Volatile to fixed combustible - - - -	1 : 1.513

The earthy residuum, from the analyses of the two specimens *a* and *b*, was of a dark brown color. The clinker was compact, of a reddish brown color, not in large masses; vitrified, but containing small bits of light slaty matter. When pulverized and recalcined, it became of a deep brown, or dark red color.

The residue from reincineration of the ashes is rather lighter red than that of the clinker, while the soot gave a still lighter colored ash, but not lighter than that of ordinary hard-burned brick.

The weight per cubic foot of the several residua, as drawn from the furnace, was as follows, viz:

Ashes - - - - - - -	53.70 pounds.
Clinker - - - - - - -	40.12 "
Soot - - - - - - -	3.92 "

When tested with the oxide of lead, specimen *a* yielded 27.074 times its weight of metallic lead; and this, after deducting moisture and ashes, gives of lead to 1 of combustible 27.884.

In the chain shop, 60 pounds of this sample were sufficient to make 13 links of a chain 1⅜ inch in diameter; gave a good fire for the purpose, and yielded but a moderate quantity of cinder.

In the anchor shop, where it was tried on ordinary smith's work, it gave a good hollow fire, and worked in a manner highly satisfactory in regard to its action on the iron.

In an ordinary domestic grate, it takes fire promptly; burns, as in the furnace, with a long flame, accompanied with much smoke; swells up, and cements into a spongy mass, leaving a light porous coke.

The time required to bring the boiler into steady action was—

In the *first* trial - - - - - -	0.833 hour.
In the *second* trial - - - - - -	0.750 "
In the *third* trial - - - - - -	0.366 "
In the *fourth* trial - - - - - -	1.500 "
Mean - - - - - - -	0.862 "

The weight of coke left after each trial was 11.06 pounds.

TABLE CLXVI.—

First trial—upper damper 8 inches open; air plates open;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 25	5.10	68	66	137	-	76 5	176	73	30.12	0.353	7.02	0.09	-	-
	6.30	72	67.5	130	240	78	210	72	30.13	0.420	6.35	0.20	-	-
	7.10	76	70	136	237	78	230	74	30.14	0.543	5.14	0.21	-	92.75
	7.25	74	69	140	246	78	232	74	30.14	0.546	5.11	0.31	-	101.75
	8.00	77	70	149	286	78	232	76	30.14	0.553	5.04	0.30	484	-
	8.30	80	72	178	312	78	233	77	30.14	0.567	4.92	0.48	1036	99.00
	9.00	82	73	212	328	78	232	79	30.14	0.541	5.16	0.30	1551	101.75
	9.30	86	74	235	314	78	233	81	30.16	0.547	5.10	0.35	2044	-
	10.00	85	75	251	343	78	-	82	30.17	0.543	5.14	0.34	2539	98.25
	10.30	86	75	267	322	78	232	83	30.16	0.547	5.10	0.37	3014	92.50
	11.15	87	75	286	331	76	232	84	30.16	0.551	5.06	0.40	3766	92.00
	P. M. 0.00	90	76	312	324	77	232	83	30.16	0.547	5.10	0.38	4796	98.00
	0.30	91	76	325	348	76	228	84	30.15	0.547	5.10	0.38	5393	94.50
	1.00	90	76	332	350	76	226	84	30.15	0.544	5.13	0.35	5893	95.00
	1.30	92	76	344	-	77	228	84.5	30.16	0.520	5.37	0.27	6221	92.00
	2.00	91	76	340	302	78	226	84.5	30.16	0.525	5.32	0.28	6940	-
	2.30	91	76	350	310	82	226	85	30.12	0.508	5.49	0.20	7180	-
	3.30	89	76	343	284	82	224	84	30.12	0.513	5.44	0.20	6899	-
	3.45	87	75	340	264	82	225	84	30.12	0.515	5.42	0.20	7643	-
	A. M.													
Aug. 26	5.25	76	70	200	192	82	214	76.5	30.16	0.370	6.86	0.09	7651	-
	5.45	76	70	195	192	82	210	76	30.16	0.352	7.03	0.11	8026	-

Period of steady action, from 7*h*. 25*m*. a. m. to 1*h*. 43*m*. p. m. = 6*h*. 18*m*.; coal supplied to furnace, for this period, 863 lbs.; water to boiler, same time, 6,562 lbs.; water to 1 of coal, 7.569.

LIVERPOOL COAL.

steam thrown into chimney, and small furnace in action.

		gases.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—*Grate surface* 14.07 *square feet; length of circuit of heated gases* 121 *feet; height of chimney* 63 *feet.*
h. m.					
–	64.9	69	–	–	Morning clear; wind NE., light; commenced firing; water 0.13 inch below normal level.
–	65.2	68	+90	–	Placed 28 lbs. of this coal in kettle to dry; water 0.3 inch above normal level.
7.10	67.3	60	7	–	Wood consumed, 218½ lbs.; commenced charging with coal.
7.25	66.6	66	14	–	Coal ignites promptly; steam escapes at 7*h.* 16*m.* a. m.; set damper at 8 inches, and opened air plates.
–	66.9	72	64	2.274	
8.26	68.8	98	79	2.924	
9.08	69.6	130	96	2.729	
–	[illegible]	149	81	2.612	Dense black smoke in large volumes from chimney.
10.00	71 6	166	–	2 859	Thermometer, indicating temperature of water in boiler, broken, and replaced by another.
10.30	71.2	181	90	2.516	
11.04	70.9	[illegible]	99	[illegible]	Filled tank at 11*h.* 0*m.* a. m.; smoke 20 seconds in reaching chimney top; syphon 0.40.
11.36	71 6	232	92	[illegible]	Volumes of dense black smoke from chimney after charging.
0.12	71.2	234	120	[illegible]	Changed thermometer in boiler; commenced drawing gases at 1*h.* 18*m.* p. m.; drew in 30 minutes 100 cubic inches, which gave water 1.27 grain, carbonic acid 5.28 grains, oxygen 12.50 cubic inches.
1.18	71.6	242	124	2.702	
1.49	70.9	252	–	1.738	
–	71.2	249	76	3.309	Filled tank at 2*h.* 35*m.* p. m.
–	71.2	250	94	1.971	Air plates closed; wind E., light; but little material from ash pit to throw on grate; at 3*h.* 30*m.* p. m. damper reduced to 3 inches.
–	71.6	254	64		
–	70.9	253	89	–	Water in boiler left at 0.3 inch above normal level.
–	67.3	124	—22	–	Water found 0.6 inch below normal level.
–	67.8	119	—18	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	23.00
Ashes	26.25
Ashes behind bridge	1.47
Total clinker and ashes	50.72
Deduct wood ashes	0.67
Total waste from coal	50.05
Coke	7.25

TABLE CLXVII.—

Second trial—upper damper 3 inches open; air plates closed;

Date.	Hour.	Temperatures of the open air entering below ash pit.	Temperatures of the wet bulb thermometer.	Temperatures of the air entering back of grate.	Temperatures of the gas entering chimney.	Temperatures of the water in tank.	Temperatures of the steam in boiler.	Temperatures of the attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 26	6.45	76	70	195	192	82	210	76	30.16	0.352	7.03	0.11	-	-
	7.15	80	75	185	264	82	228	76	30.16	0.530	5.27	0.23	-	93.00
	7.30	79	75	180	274	82	229	77	30.16	0.548	5.14	0.30	80	95.75
	8.00	81	75	184	308	82	232	77	30.16	0.542	5.14	0.32	417	93.25
	8.30	82	76	208	335	82	230	79	30.16	0.547	5.10	0.35	842	-
	9.00	84	77	250	350	82	-	80	30.16	0.560	5.07	0.40	1355	96.50
	9.30	85	77	288	355	82	229	81	30.18	0.543	5.14	0.38	1866	93.25
	10.00	86	77	296	366	82	230	81	30.18	0.551	5.06	0.38	2352	-
	10.30	87	77	318	350	82	230	82	30.18	0.543	5.14	0.35	2850	97.00
	11.00	88	77	337	347	82	230	83	30.17	0.553	5.04	0.40	3362	92.00
	11.30	91	78	344	371	79	230	84	30.17	0.539	5.18	0.31	3916	95.75
	P. M.													
	0.00	91	79	348	350	79	230	85	30.17	0.545	5.12	0.35	4342	-
	0.30	95	80	372	332	78	230	85	30.18	0.545	5.12	0.35	4767	96.50
	1.00	95	80	382	348	79	230	86	30.17	0.540	5.17	0.33	•5266	91.50
	1.30	94	80	384	342	79	229	86	30.17	0.528	5.33	0.30	5699	-
	2.00	96	80	385	320	79	228	87	30.17	0.521	5.36	0.29	6042	-
	3.00	94	79	328	270	83	227	88	30.15	0.504	5.52	0.20	6192	-
	A. M.													
Aug. 27	6.25	79	74	192	196	83	207	80	30.18	0.351	7.04	0.13	6202	-
	7.00	80	75	192	194	83	206	80	30.18	0.351	7.04	0.13	6671	-

Period of steady action, from 8*h.* 15*m.* a. m. to 1*h.* p. m.—4*h.* 45*m.* Coal supplied to grate, 662.5 lbs.; water supplied to boiler, 4,637 lbs.; water to 1 of coal, 6.999.

LIVERPOOL COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	67.3	119	—18	-	Commenced firing; water in boiler 0.2 inch above normal level; wind SW.; clear.
7.15	73.2	105	+36	-	Wood consumed, 118½ lbs.; commenced charging with coal.
7.35	73.5	101	45	0.848	
8.15	72.8	103	76	1.785	Wind W.; sun shining.
-	73.9	126	105	2.252	
8.45	74.7	166	-	2.718	Smoke (mean of 2 observations) 16 seconds in reaching chimney top; syphon 0.40.
9.35	74.4	203	126	2.707	
-	74.1	210	136	2.575	
10.24	73.8	231	120	2.638	
11.00	73.5	249	117	2.712	Filled tank at 11*h*. 25*m*. a. m.
11.30	74.1	253	141	2.935	Commenced drawing gases from lower damper at 11*h*. 29*m*.; drew in 27 minutes 100 cubic inches, which gave water 1.07 grain, carbonic acid 5.81 grains, oxygen 9.375 cubic inches.
-	75.5	257	120	2.257	
0.20	75.9	277	102	2.252	
1.00	75.9	287	118	2.644	Fire declining; no smoke.
-	76.1	290	113	2.294	
-	75.7	289	92	1.817	
-	74.7	234	43	-	Filled tank; damper set at 3 inches at 2*h*. 45*m*. p. m.; water 0.3 inch above normal level.
-	72.1	113	—11	-	Water 0.85 inch below normal level; morning cloudy.
-	73.2	112	—12	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	19.75
Ashes - - - - - - - - - -	24.75
Ashes behind bridge - - - - - - - - -	1.30
Total clinker and ashes - - - - - - - -	45.80
Deduct wood ashes - - - - - - - - -	0.362
Total waste from coal - - - - - - - -	45.438
Coke - - - - - - - - - -	5.25

TABLE CLXVIII.—

Third trial—upper damper 4 inches open;

Date.	Hour.	Temperatures of the Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 28	4.30	80	74	150	–	82	183	79.5	30.11	0.350	7.06	0.09	–	–
	5.40	78	74	144	262	82	200	78.5	30.11	0.386	6.68	0.15	–	–
	6.38	78	74	150	260	82	227	78	30.11	0.520	5.37	0.16	–	97.00
	7.00	77.5	74	154	262	82	228	78	30.12	0.523	5.34	0.20	–	97.00
	7.30	79	75	160	256	83	227	78	30.12	0.536	5.21	0.26	256	–
	8.00	80	76	179	282	83	228	79	30.12	0.534	5.23	0.24	513	–
	8.30	82	77	214	270	82	228	79	30.12	0.529	5.28	0.21	766	94.50
	9 00	84	75	247	274	83	229	80	30.12	0.526	5.31	0.22	1021	–
	9.30	86	78	286	268	83	229	80	30.12	0.535	5.22	0.22	1276	–
	10.00	86	78	321	273	83	229	81	30.14	0.530	5.27	0.22	1631	99.00
	10.30	89	79	344	268	83	230	81	30.14	0.525	5.32	0.20	1751	96.00
	11.00	90	80	365	264	83	229	81	30.14	0.529	5.28	0.22	2111	–
	11.30	90	79	380	276	83	229	82	30.14	0.529	5.28	0.21	2371	100.00
	P. M. 0.05	91	79	397	282	82	230	83	30.14	0.531	5.26	0.22	2669	–
	0.30	92	80	402	292	82	229	83	30.13	0.525	5.32	0.22	2872	109.00
	1.00	95	81	416	289	82	229	84	30.12	0.527	5.30	0.22	3124	–
	1.30	95	80	428	275	82	229	84	30.12	0 523	5.33	0.21	3358	96.50
	2.00	96	81	413	300	82	229	85	30.11	0.522	5.35	0.22	3704	–
	2.30	98	83	422	300	82	229	85	30.10	0.527	5.30	0.22	3926	97.50
	3.00	99	83	422	296	81	229	85	30.10	0.531	5.26	0.22	4254	–
	4.00	98	82	413	280	83	228	85	30.10	0.517	5.40	0.18	4661	–
	5.30	88	78	406	254	83	226	86	30.11	0.493	5.63	0.16	4911	–
Aug. 29	A. M. 5.45	79	75	220	194	83	215	79	30.19	0.407	6.50	0.11	4919	–
	6.00	79	75	217	196	83	213	79	30.18	0.370	6.86	0.11	5323	–

Period of steady action, from 7*h*. a. m. to 2*h*. 30*m*. p. m.—7*h*. 30*m*.; coal supplied to furnace, 656.5 lbs.; water to boiler, 3,926 lbs.; water to 1 of coal, 5.864.

LIVERPOOL COAL.

air plates closed; steam thrown into chimney.

–	71.7	70	–	–	Commenced firing; water 0.02 inch below normal level, morning cloudy; wind NE., light.
–	73.5	66	+62	–	Water in boiler adjusted at ±0. at 200°.
6.38	72.5	[illegible]	33	–	Wood consumed, 207 lbs.; commenced charging with coal.
7.00	71.95	76.5	34	–	Steam blows off at 6*h*. 50*m*.
–	73.5	81	29	[illegible]	
–	74.6	99	56	1.362	Wind SW., light; cloudy at 8*h*. 15*m*.
8.25	75.3	132	42	1.340	Wind NE. at 8*h*. 50*m*.
–	71.6	163	45	1.351	Gas 24 seconds in reaching chimney top; syphon 0.21.
–	75.5	200	39	1.351	
9.43	75.5	235	44	1.881	Wind SW. at 9*h*. 45*m*.
10.24	76.0	255	38	0.636	
–	77.2	275	35	1 906	The three preceding observations, with this one, give an average of 1.474 lb. of water to the square foot of heating surface. The irregularity was produced by the letting in of water to the boiler.
11.30	76.0	290	47	1.377	
–	75.5	306	52	1.350	
0.30	76.6	310	63	1.286	Filled tank at 11*h*. 55*m*.
–	77.3	321	60	[illegible]	Occasional sunshine.
1.30	75.9	333	[illegible]	1.289	
–	74.2	317	71	1.633	
2.30	75.9	324	71	1.176	
–	72.1	323	57	1.737	Contents of ash pit thrown on grate.
–	76.0	315	52	–	Filled tank at 3*h*. 50*m*.
–	74.9	318	26	–	Water left at 0.26 inch above normal level.
–	73.5	141	—21		
–	73.5	139	—17	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	16.00
Ashes	35.00
Ashes behind bridge	1.19
	52.19
Deduct wood ashes	0.635
Total waste from coal	51.555
Coke	17.25

TABLE CLXIX.—

Fourth trial—upper damper 8 inches open; air plates open;

Date.	Hour.	TEMPERATURES OF THE Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 29	6.00	79	75	217	196	83	213	79	30.18	0.370	6.86	0.11	-	-
	7.00	79.5	76	216	278	83	227	78	30.19	0.520	5.36	0.21	-	92.50
	7.20	80	76	215	301	83	229	78	30.19	0.535	5.22	0.27	-	91.75
	8.00	81	77	222	318	83	229	79	30.19	0.533	5.24	0.28	418	-
	8.30	81	76	240	324	83	229	79	30.20	0.543	5.14	0.31	753	91.25
	9.00	82	77	272	348	83	229	79	30.20	0.548	5.10	0.32	1008	-
	9.30	83	76	304	334	83	229	79	30.21	0.538	5.20	0.30	1425	95.75
	10.00	86	78	318	334	84	229	80	30.21	0.538	5.20	0.30	1685	-
	10.30	87	78	329	332	84	229	80	30.21	0.538	5.20	0.30	2090	91.75
	11.10	88	78	343	318	84	229	81	30.21	0.545	5.12	0.31	2575	-
	11.40	87	78	330	-	81	229	82	30.21	0.543	5.14	0.33	3090	97.00
	P. M. 0.00	87	78	336	390	82	229	83	30.21	0.545	5.12	0.38	3424	97.25
	0.30	90	80	355	396	81	229	83	30.21	0.543	5.14	0.36	3930	96.00
	1.00	87	78	358	396	82	229	83	30.21	0.535	5.22	0.35	4355	-
	1.35	89	80	366	386	82	228	83	30.20	0.536	5.20	0.33	4952	99.00
	2.00	90	80	372	402	82	228	84	30.20	0.533	5.24	0.31	5294	95.50
	2.30	89	78	377	392	82	228	84	30.18	0.533	5.24	0.27	5734	-
	3.20	93	79	374	336	82	226	84	30.18	0.512	5.45	0.23	6021	-
	3.45	87	78	375	320	82	226	84	30.19	0.519	5.38	0.22	6261	-
	6.40	84	77	325	250	82	224	81	30.19	0.507	5.50	0.16	6263	-
	7.05	85	77	311	245	83	221	81	30.19	0.471	5.84	0.14	6648	-
Aug. 30	A. M. 5.40	76	74	201	-	82	212	77	30.19	0.362	6.94	0.00	6714	-

Period of steady action, from 8*h.* 20*m.* a. m. to 2*h.* 10*m.* p. m.=5*h.* 50*m.*; coal supplied to grate in that period, 672.25 lbs.; water supplied to boiler, 4,799 lbs.; water to 1 of coal, 7.138.

LIVERPOOL COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by			
h. m.					
-	73.5	138	—17	-	Commenced firing; water 0.14 inch above normal level; morning cloudy; wind NE.
7.00	74.8	136.5	+51	-	Wood consumed, 111 lbs.; commenced charging with coal; steam escapes at 7*h.* 15*m.*; air plates opened at 7*h.* 20*m.*
7.20	74.6	135	72		
-	75.6	141	89	1.661	Damper reduced to 8 inches at 9*h.* 20*m.*
8.20	74.2	159	95	1.775	
-	75.3	190	119	1.351	
9.18	73 6	221	105	2.209	
-	75.5	232	105	1.378	
10.27	75.2	242	103	2.146	Commenced drawing gases from lower opening at 11*h.* 6*m.*, drew in 36.5 minutes 100 cubic inches, which gave water 1.09 grain, carbonic acid 6.19 grains, oxygen 9.688 cubic inches.
-	74.9	256	89	1.827	
11.16	75.2	243	-	2.728	
11.46	75.2	249	161	2.389	Smoke 18.5 seconds in reaching chimney top; syphon 0.38.
0.30	77.2	265	167	2.681	Raining.
-	75.2	271	167	2.252	Ceased raining.
1.12	77.4	277	156	2.711	
2.10	77.2	282	174	2.174	Wind E., brisk; sun shining.
-	74.6	288	164	2.331	Filled tank at 3*h.* 10*m.*
-	75.0	281	110	0.912	Air plates closed; contents of ash pit thrown on grate.
-	75.2	288	94	-	Damper reduced to 3 inches; water left at 0.4 inch above normal level.
-	74.7	241	26		
-	74.4	226	24	-	Water again brought 0.83 inch above normal level.
-	73.2	125	-	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	12.00
Ashes - - - - - - - - - - -	29.25
Ashes behind bridge - - - - - - - - -	1.29
Total clinker and ashes - - - - - - - -	43.54
Deduct wood ashes - - - - - - - - -	0.338
Total waste form coal - - - - - - - -	42.202
Coke - - - - - - - - - - -	14.50
Soot - - - - - - - - - - -	16.25

TABLE CLXX.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (Tab. CLXVI.)	2d Trial. (Tab. CLXVII.)
		August 25.	*August* 28.
1	Total duration of the experiment, in hours	24.583	25.25
2	Duration of steady action, in hours	6.30	4.75
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	11.0	10.0
7	Total weight of coal supplied to grate, in pounds	1057.5	944.5
8	Pounds of coal actually consumed	1050.25	939.25
9	Pounds of coal withdrawn and separated after trial	7.25	5.25
10	Mean weight, in pounds, of one cubic foot of coal	48.067	47.225
11	Pounds of coal supplied per hour, during steady action	136.98	139.47
12	Pounds of coal per square foot of grate surface, per hour	9.735	9.912
13	Total waste, ashes and clinker, from 100 pounds of coal	4.766	4.798
14	Pounds of clinker alone, from 100 pounds of coal	2.1585	2.0868
15	Ratio of clinker to the total waste, per cent.	45.295	43.138
16	Total pounds of water supplied to the boiler	8026.0	6671.0
17	Mean temperature of water, in degrees Fahrenheit	77.8	80.9
18	Pounds of water supplied at the end of experiment, to restore level	375.0	469.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	48.6	59.0
20	Pounds of water evaporated per hour, during steady action	1036.98	976.2
21	Cubic feet of water per hour, during steady action	16.592	15.616
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.746	2.585
23	Pounds of water per square foot, by a mean of several observations	2.755	2.569
24	Water evaporated by one of coal, from initial temperature (a) final result	7.596	7.039
25	Water evaporated by one of coal, from initial temperature (b) during steady action	7.569	6.999
26	Pounds of fuel evaporating one cubic foot of water	8.228	8.879
27	Mean temperature of air entering below ash pit, during steady pressure	85°.46	87°.73
28	Mean temp. of wet bulb thermometer, during steady pressure	74°.08	77°.55
29	Mean temperature of air, on arriving at the grate	259°.3	302°.45
30	Mean temperature of gases, when arriving at the chimney	317°.17	346°.55
31	Mean temperature of steam in the boiler	230°.5	230°.1
32	Mean temperature of attached thermometer	81°.23	82°.09
33	Mean height of barometer, in inches	30.153	30.165
34	Mean number of volumes of air in manometer	5.127	5.116
35	Mean height of mercury in manometer, in atmospheres	0.5445	0.5454
36	Mean height of water in syphon draught gauge, in inches	0.350	0.360
37	Mean temperature of dew point, by calculation	70°.11	74°.43
38	Mean gain of temperature by the air, before reaching grate	173°.84	214°.72
39	Mean difference between steam and escaping gases	91°.1	120°.55
40	Water to one of coal, corrected for temp. of water in cistern	7.5698	7.012
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	8.5546	7.9038
42	Pounds of water, from 212°, to one cubic foot of coal	411.20	373.25
43	Water, from 212°, to one pound of combustible matter of the fuel	8.9827	8.3020
44	Mean pressure, in atmospheres, above a vacuum	1.4424	1.4462
45	Mean pressure, in pounds per square inch, above atmosphere	6.5334	6 5905
46	Condition of the air plates at the furnace bridge	Open.	Closed.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

TABLES CLXVI, CLXVII, CLXVIII, CLXIX.

Liverpool coal.

3d Trial. (Tab. CLXVIII.)	4th Trial. (Tab. CLXIX.)	Averages.	Remarks.
August 28.	*August* 29.		
25.50	23.667		
7.50	5.833		
14.07	14.07		
377.5	377.5		
18.75	18.75		
9.0	10.0		
880.5	947.75		
863.25	933.25		
17.25	14.50	11.062	The coke left on the third trial, when the damper was but four inches open, was nearly 3½ times as much as in the preceding trial.
48.9165	47.3875	47.899	
91.533	115.249	120.807	
6.505	8.191	8.5858	
5.972	4.634	5.0425	
1.8303	1.3812	1.8642	
30.647	29.838	37.2295	
5328.0	6714.0		
82°.4	82°.0		
403.0	66.0		
51.0	8 0		
523.46	822.73	839.802	
8.376	13.16	13.435	
1.386	2.179	2.224	
1.385	2.177		
6.107	7.185	6.9818	The effect of closed air plate and a four-inch damper is very distinctly manifested in the third trial, diminishing the efficiency of the fuel by about one seventh part of its whole amount.
5.864	7.138	6.8925	
10.2342	8.6987	9.01	
89°.5	85°.8		
78°.875	77°.87		
337°.25	315°.8	303°.7	
279°.06	355°.07	324°.462	The gases arrived at the chimney at the highest temperature in the fourth trial, when the greatest accumulation of soot was on the absorbing surfaces.
228°.875	228°.80		
81°.87	81°.13		
30 124	30.203		
5.2825	5.181		
0.5287	0.5391		
0.2206	0.3263	0.3142	
75°.18	76°.39		
247°.75	230°.0	216°.57	
49°.2	134°.8	111°.412	
6.0826	7.1563	6.9552	
6.8508	8.0595	7.842	
336.09	381.91	375.362	
7.2854	8.4511	8.2553	
1.4016	1.4374	1.4318	
5.9294	6.4595	6.3782	
Closed.	Open.		
U. 4.	U. 8.		

Remarks on the preceding table of deductions.

In examining the second and third columns of this table, it will be observed that the rate of combustion with a 4-inch damper was but 6.505 pounds per square foot of grate per hour; while on the preceding trial, with an 8-inch damper, it had been 9.912 pounds. Hence the diminution in combustion, by throttling the smoke, was 34.2 per cent. The 13th line shows that on the third trial (with a 4-inch damper) the total waste was 5.97 per cent. of the coal; whereas the second trial had yielded but 4.80 per cent., or the augmentation of waste was 24 per cent. of the latter number.

The rate of evaporation fell from 2.585 pounds per square foot of heated surface per hour (as seen in line 22) on the second trial, to 1.386 on the third. The loss in rapidity of evaporation is 46.3 per cent.; from this deducting the loss in rapidity of combustion, we obtain 12.1 per cent. as the actual loss in useful effect of the fuel. This, it will be observed, is obtained from the approximate results derived from the period of steady action.

The same conclusion follows, however, from data entirely independent of the preceding. Thus the 43d line shows that on the second trial the unit of combustible matter evaporated from 212°, 8.302 of water, and on the third trial only 7.2854; the difference, 1.0166, is 12.2 per cent. of the larger number.

The air reached the grate at a temperature 337.25—302.45=34°.8 hotter on the third than on the second day of trial—an effect due to its slower movement, and the consequent higher temperature of the inner walls through which it received its heat. This shows that the higher temperature of the air which supplies the furnace is not alone sufficient to secure a more perfect combustion.

It also appears that the gases left the boiler and passed into the chimney on the second day of trial at 346°.55, and on the third at 279°.06; so that they did not carry away *more*, but, on the contrary, 67.5 *less* heat in the latter case than in the former.

The imperfection of combustion, consequent on a want of sufficient air to consume the gaseous products, is here the obvious source of inferiority in result. Both the second and the third trials, it will be observed, were made with air plate closed.

A comparison of the *first* with the *fourth* trial shows what effect is to be attributed to the soot of the flues from three days' operations in diminishing evaporative efficiency. Both trials were made with air plate open, and the upper damper drawn 8 inches. The coal burned per hour on the first day was 136.98, and on the fourth 115.25 pounds. The difference is 15.8 per cent. of the former number. The rate of evaporation was 16.592 cubic feet per hour on the first, and 13.16 on the fourth trial. The difference, 3.432 cubic feet, is 20.7 per cent. of the larger number. From this deducting 15.8, the remainder, 4.9, indicates the loss of useful effect of the fuel in consequence of the imperfect conduction of the coating of the boiler and flues. This is a result from the observations during the period of steady action. In line 43 is found 8.9827 in the column of the first, and 8.4511 in that of the fourth trial. The difference of these, 0.5316, is 5.9 per cent. of the larger number. The approximate result from steady action, and that from the final amount of evaporation, again confirm each other in their general indication, and differ but by 1 per cent. in the proportion of loss.

No. 5.

Bituminous coal from Newcastle, England, procured for comparative experiments, from Messrs. Laing & Randolph, of New York.

In many of its external characters, this coal strongly resembles the Midlothian and Chesterfield coals of the Richmond district. Its planes of deposition are not always followed by the cleavages in that general direction. Some unevenness frequently occurs, revealing conchoidal surfaces of a pitchy appearance. The main partings are mostly at right angles to the horizontal seams. Scales and laminæ of carbonate of lime, and probably of magnesia, exist throughout the partings. They effervesce moderately with nitric acid. Sulphuret of iron is seen in contiguity with this earthy deposite. When reduced to an impalpable powder, this coal has a light brown color, indicative of high bituminousness.

The specific gravity of one specimen (*a*) was found to be 1.2844; that of another, (*b*,) 1.2291; the mean of the two giving the calculated weight per cubic foot, 78.54 pounds.

Forty trials in the charge box, of which the *least* result was 48.375, and the greatest 53, afforded an *average* of 50.8218 pounds per cubic foot, or 0.647 of the calculated weight. The space required for one ton is, consequently, 44.076 cubic feet.

In specimen *a* the moisture was 0.993, and in *b* 0.926 per cent.

Twenty-eight pounds dried in the steaming apparatus for four days lost 9 ounces, or 2.007 per cent.

The sulphur obtained from *b* was 0.23 per cent. Of volatile matter other than moisture, *a* gave 33.597; and *b*, by the mean of two trials, gave 40.355 of volatile matter, including moisture and sulphur.

The earthy residuum of *a* was 3.75, that of *b* 1.85 per cent.

Hence, the proximate constituents of these two specimens may be stated as follows:

	Specimen *a*.	Specimen *b*.
Moisture - - - - -	0.993	0.926
Sulphur - - - - -	(not tried)	0.230
Other volatile matter - -	33.557	39.199
Earthy matter - - - -	3.750	1.850
Fixed carbon - - - -	61.700	57.795
	100.	100.
Volatile to fixed combustible -	1 : 1.8387	1 : 1.4744

The pasty state into which the coal is brought during the coking process, causes portions of gas to become temporarily confined within the semi-fluid mass. When, at length, these become sufficiently elastic to burst the enclosure, jets of flame, accompanied with smart explosions, and possessing a high illuminating power, are frequently observed. In these analyses it was found expedient to confine the lid of the platinum crucible, to avoid its being thrown off by the cause just referred to.

The total volatile matter from two specimens tried by Dr. King was 39.083 and 36.125, respectively, or a mean of 37.604. Combined with the two above given, this result would afford for the total volatile matter 37.528.

During four trials of evaporative power, there were burned 4,023 lbs. of this coal, yielding, of—

Ashes - - - - - - -	104.76 lbs.
Clinker - - - - - -	126.00 "
Soot - - - - - - -	16.25 "
The incombustible matter in the—	
Ashes, was - - - - - -	89.377 lbs.
Clinker - - - - - -	126.000 "
Soot - - - - - - -	4.381 "
Total - - - - - -	219.758 "
Deduct ashes of 822.75 lbs. of wood - -	2.526 "
And there remain of incombustible matter of the coal - - - - - - -	217.232 "

= 5.3997 per cent.

From these data, we may infer that the sample had the following proximate constituents:

Moisture, (from drying 28 lbs.) - - - -	2.007
Other volatile matter, (from two trials by Dr. King)	35.597
Earthy matter, (from 4,023 lbs.) - - -	5.400
Fixed carbon, (calculated by difference) - -	56.996
	100.

Volatile to fixed combustible 1 : 1.6011.

The ashes derived from this sample weighed 51.11 lbs. per cubic foot; the clinker, 38.25; and the soot (which, with a single exception, is the lightest obtained from any coal examined) weighed but 3.7 lbs. per cubic foot.

The clinker is in thin sheets, of a dark color, with small portions of slaty residuum, whitening the otherwise nearly black compact vitrified masses. It is highly fusible, and adheres to the grate.

By means of the oxide of lead, specimen *b* produced the reduction of 26.785 times its weight of metallic lead; which, after deducting 2.776 parts for moisture and ashes, gives for one of combustible matter in the coal 27.55 times its weight of lead.

This coal was submitted, in addition to the above trials, to the following analysis:

Forty specimens were selected from the different casks—about an equal number from each. A small fragment was detached from each specimen, and the whole were pulverized together. Of the fine powder, 55.9 grains were placed on a platinum capsule, to incinerate in the muffle of an assay furnace, where it became completely reduced, leaving only 2.1 grains, or 3.756 per cent. of waste.

Of the same powder, 102.5 grains were thoroughly dried at a temperature below 250°, losing thereby 1.38 grain, or 1.346 per cent.

The same portion, closely covered, was then coked slowly, and finally kept for some time at a full red heat in the muffle, till all inflammable matter had ceased to escape; after which, it weighed 72.1 grains.

This shows that the total volatile matter, by this mode of treatment, is 29.658 per cent.

Hence, the proximate constituents are—

Moisture - - - - - - -	1.346
Other volatile matter - - - - -	28.312
Earthy matter - - - - - -	3.756
Fixed carbon - - - - - -	66.586
	100.

And volatile to fixed combustible - - - 1 : 2.3519

In all the other determinations of volatile matter, the method of rapid coking was pursued; and the difference, as above seen, is very striking. By rapid coking, the weight of coke obtained from specimen *a*, above analyzed, was less by 6.95, and that from *b* by 15.21 per cent., than from the average specimen just presented.

This coal was also subjected to analysis by the scale oxide of copper.

109.5 grains were thoroughly dried, and proved that the moisture had been 1.6 grain, or 1.461 per cent.

The same specimen had been found to contain 1.85 per cent. (of the raw coal) in earthy matter, which is 1.877 of the dried coal.

6.46 grains of this dried coal, containing 0.1212 grain of ashes, gave—

Of water - - - - - -	3.21 grains.
Of carbonic acid - - - - -	19.56 "
Hence the—	
Hydrogen is - - - - -	0.3566 grains.
Carbon - - - - - -	5.3345 "
Earthy matter - - - - -	0.1212 "
	5.8123 "
And by difference, the oxygen and azote are -	.6477 "
Making - - - - - -	6.46 "

= the weight of dry coal employed.

As this weight of dried coal came from 6.5558 grains of *raw coal*, the latter number must be used in obtaining the proportion of ingredients in that state.

Hence the moisture is - - - - -			1.461
Carbon - - - -	5.3345	÷ 6.5558	= 81.371
Hydrogen - - -	.3566	÷ 6.5558	= 5.439
Oxygen, &c. - - -	.6477	÷ 6.5558	= 9.879
Earthy matter - - - - - -			1.850
			100.

As the sum of the combustible ingredients is 96.689, the relation of these to each other is obtained as follows:

Carbon - - - - - - - -	84.157	= 14.026 atoms.
Hydrogen - - - - - -	5.626	= 5.626 "
Oxygen and azote, estimated as oxygen alone -	10.217	= 1.252 "
	100.	

If, from the data furnished by this analysis, we would *calculate* in the usual way the heating power of the raw coal, we must first deduct from the weight of hydrogen (5.439) one-eighth the weight of oxygen, (1.2348 grain,) which leaves of that combustible 4.2042 grains; and if, with Despretz, we adopt for the heating power of hydrogen 42552° Fahrenheit, (236400 centigrade,) then will 1789° express the heating power of this ingredient. And if, with the same author, we admit the heating power of carbon to be 14040° Fahrenheit, (7800 cent.,) then $0.81371 \times 14040 = 11424°$, will represent the heating power of the carbon present, supposing it to be converted into carbonic acid. The numbers $11424 + 1789 = 13213$, express the pounds of water capable of being heated 1° Fahrenheit by the combustion of 1 pound of the raw coal; and in order to convert this into terms of the standard employed in the researches on evaporation, it is only necessary to divide this number by 1030, the latent heat of the vapor of water, which will give the theoretical evaporative power of the pound of coal, equal to the production of 12.828 pounds of steam from water at 212°. Now, the maximum evaporative power obtained was 9.0706 pounds of water from 212°, to 1 pound of coal burned. The difference of these two is 29.29 per cent. of the theoretically computed heating power.

If, instead of the numbers given by Despretz, we prefer those obtained by Dulong, viz: 62535 for hydrogen, and 12906 for carbon, the calorific power of the former will be $0.042042 \times 62535 = 2629$; and that of the latter, $0.81371 \times 12906 = 10521$; and the sum of these two, 13150, differs but little from the number obtained from using the data of Despretz.

No experiments were made on the gases passing into the chimney while burning *this* coal, so that I am not able to present the total heating power expended on the air which supplied combustion, the moisture of that air, and the water generated from the coal itself, as has been done in a subsequent table with regard to many other samples. If, however, we compare the effect produced by coals nearly analogous to it, and which have been tried in that manner, it will be evident that this theoretical result of 12.828 pounds of water to 1 of highly bituminous coal, was in no instance even approached. Seven trials on the Midlothian coal of Virginia gave for the heating power, measured by the steam alone, 8.4786, and by all the means ...d, 10.068; the difference, 1.59, is only 15.78 per cent. of the

... It seems not to have been considered, by those who have ...rmine the heating power of fuel for practical purposes, by ... efficiency of its hydrogen constituent, that the hydrogen on ...s have operated to demonstrate its heating power had al...ught to the elastic state, at the expense of a large quantity ...ced to the latent state; while in *fuel*, it is either in the solid ...t the commencement of the process of combustion. The

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* To compare the evaporative power of the unit of combustible matter in Newcastle coal, as determined by the actual evaporation, with that derived from the *carbon* found in its combustible ingredients, as proved by ultimate analysis, recourse is had to the *average* in the 43d line of the table of deductions, which is 9.1777; and as, by what is stated in the text, this may be taken for $1 - 0.1578 = 0.8422$ of the total evaporative power, therefore $9.1777 \div 0.8422 = 10.898$ = the total evaporative power of the unit of combustible matter in the coal, as proved by the steaming operations. And as 0.84157 is the proportion of carbon in 1 of the *combustible matter* of the coal, by ultimate analysis, therefore $\frac{0.84157 \times 12906}{1030} = 10.545$ = the evaporative power of the carbon alone, calculated from chemical composition. In addition to the above researches which have been made

practical bearing of this difference becomes the more important in cases where the products of combustion necessarily pass away from the surfaces to be heated, at a temperature above boiling point. The vapor of water at ordinary atmospheric pressure has the same bulk as the hydrogen from which it had been ger
in forming it, had onl
bon, forms carbonic a
condensed into it. Ir
Rumford, the watery
employing cold surfa
the vapors generated
can this be considerec
steam boiler. The la
keeps their masses at
chief materials burne
be employed in raisin
heat by radiation, as
even when bituminou
lapse of a considerabl
the Newcastle coal, t
50 minutes.

The coke left unburned was 10.69 pounds at each trial—about double as much as for several of the Virginia coals.

In the ar rned well, made a good hollow fire, produced but l ited no tendency to deteriorate the iron.

In the ch ut in 15 links of a chain 1⅛ inch in diameter; it wo small quantity of cinder. Between the Liverpool the difference obtained in the chain shop correspond t deduced from evaporation; the Liverpool put i d made but 7.84 pounds of steam from 212°; the N ted, put in 15 links, and evaporated 8.65 pounds of water from the same temperature.

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respecting the present sample of coal, I may cite the experiments of Mr. Richardson, who found the rich coking coal from Garesfield, near Newcastle, to contain, after being thoroughly dried—

87.[illegible] parts of carbon.
5.239 parts of hydrogen.
6.416 parts of oxygen and azote.
1.[illegible] parts of ashes.

100.

Or, deducting ashes, the other ingredients have to each other the relation of—

		Atoms.
Carbon - - -	[illegible].194 — 14.[illegible]	
Hydrogen - - -	5.[illegible] — 5.[illegible]	
Oxygen, &c. - -	6.498 — 0.696	
	100.	

Of coking coal from South Hetton, he found the composition to be—

Carbon - - - -	83.274
Hydrogen - - - -	5.171
Oxygen and azote - - -	9.036
Ashes - - - -	2.519
	100.

Deducting ashes, this gives—

Carbon - - -	85.425 — 14.237
Hydrogen - - -	5.304 — 5.304
Oxygen and azote - -	9.269 — 1.158

My specimen will be found to have been much nearer the Hetton than the Garesfield specimen of Mr. Richardson.

TABLE CLXXI.—

First trial—upper damper 8 *inches open ; air plates open ;*

Date.	Hour.	TEMPERATURES OF THE: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
Sept. 6	5.20	77	74	105	–	84	99	80	30.14	0.350	7.05	0.05	–	–
	9.05	83	76	148	248	85	226	80	30.16	0.530	5.27	0.25	–	104.75
	9.15	81	75	160	234	85	229	80	30.16	0.558	5.00	0.25	–	–
	9.30	82	76	163	248	85	228	80.5	30.16	0.540	5.17	0.30	87	101.75
	10.00	82	76	165	275	84	230	80.5	30.16	0.543	5.14	0.35	598	–
	10.30	83	76	184	290	84	229	81	30.16	0.553	5.04	0.34	1007	–
	11.00	86	77	220	298	84	230	82	30.17	0.555	5.02	0.37	1591	102.50
	11.30	86	76	243	324	84	230	83	30.16	0.553	5.04	0.38	1921	–
	P. M.													
	0.00	86	76	254	304	85	230	83	30.15	0.550	5.07	0.36	2349	99.50
	0.30	87	77	270	320	85	230	84	30.14	0.553	5.04	0.38	2776	99.75
	1.00	87	77	283	330	85	228	84	30.13	0.537	5.20	0.31	3346	–
	1.20	88	78	292	322	85	232	84	30.13	0.551	5.06	0.35	3686	99.00
	2.00	88	78	304	320	85	232	84	30.13	0.547	5.10	0.30	4361	94.50
	2.40	89	78.5	310	340	85	231	84	30.12	0.537	5.20	0.30	4882	–
	3.00	90	79	318	340	85	231	84	30.12	0.541	5.16	0.31	5219	–
	3.30	90	79	328	334	85	231	84	30.11	0.550	5.07	0.32	5644	98.25
	4.00	88	78	332	340	85	231	84	30.11	0.548	5.14	0.32	6153	100.75
	4.30	84	77	340	331	85	230	83	30.11	0.531	5.26	0.28	6640	–
	4.55	84	77	340	294	84	228	82	30.11	0.519	5.38	0.20	7010	–
	A. M.													
Sept. 7	5.40	77	74	195	190	84	215	78	30.07	0.387	6.70	0.10	7022	–
	6.00	79	74	193	188	84	213	78	30.07	0.366	6.90	0.10	7292	–

Period of steady action, from 9*h*. 30*m*. a. m. to 3*h*. 47*m*. p. m.—6*h*. 17*m*.; coal supplied to furnace, 694.25 lbs.; water supplied to boiler, 5,845 lbs.; water to 1 of coal, same time, 8.419.

NEWCASTLE COAL.

steam thrown into chimney, and small furnace in action.

-	72.8	28	-	-	Morning cloudy; wind NE., light; commenced firing; water 1.28 inch below normal level.
9.05	73.6	66	+28	-	Wood consumed, 503 lbs.; commenced charging with coal; steam at equilibrium.
-	[illegible]	89	6	-	Steam blows off.
9.20	73.9	81	20	[illegible]	Damper set at 8 inches; air plates opened.
-	[illegible]	83	45	2.707	Sun shining.
-	78.6	101	61.	2.167	
10.56	74.1	184	68	3.094	
-	72.7	157	94	1.748	Filled tank at 11*h*. 45*m*. a. m.
11.45	72.7	168	74	2.268	Smoke 18 seconds in reaching chimney top; syphon 0.36.
0.16	73.8	[illegible]	90	2.262	
-	73.8	196	102	[illegible]	Wind E., brisk; clear.
1.20	74.9	204	90	2 660	Cloudy.
1.56	74.9	216	88	2.692	Water above usual level; filled tank.
-	75.3	221	109	2.070	
-	75.8	228	109	2.678	Placed 28 lbs. of this coal in drying apparatus.
[illegible]	[illegible]	238	[illegible]	2.252	
3.47	74.9	244	109	2.697	Air plates closed, and contents of ash pit thrown on grate.
-	74.7	256	101	2.580	Filled tank at 4*h*. 15*m*. p. m.
-	74.7	256	66	-	Damper reduced to 3 inches; water left at 0.55 inch above normal level.
-	72.8	118	—25	-	Water 0.9 inch below normal level.
-	72.1	114	—25	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	44.50
Ashes - - - - - - - - - -	9.50
Ashes behind bridge - - - - - - - - -	0.63
	54.63
Deduct wood ashes - - - - - - - - -	1.544
Total waste from coal - - - - - - - -	53.076
Coke - - - - - - - - - -	5.75

TABLE CLXXII.—

Second trial—upper damper 6 inches open; air plates closed;

Date.	Hour.	Temperatures of the Open air entering below ash pit	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 7	6.00	79	74	198	180	84	218	78	30.07	0.366	6.90	0.10	-	-
	7.00	80	75	192	272	84	226	77	30.07	0.523	5.34	0.26	-	98.50
	7.15	80	75	188	258	84	228	77	30.07	0.528	5.29	0.25	-	-
	8.00	80	74	184	328	84	230	78	30.07	0.545	5.12	0.32	598	96.75
	8.30	80	74	195	358	84	230	78	30.07	0.551	5.06	0.37	848	96.75
	9.00	80	74	216	366	84	230	78	30.07	0.558	5.00	0.40	1443	-
	9.30	82	75	241	356	84	231	79	30.07	0.560	4.98	0.41	1930	101.00
	10.00	82	74	264	360	82	230	79	30.07	0.554	5.02	0.40	2346	102.75
	10.30	84	75	292	356	82	230	79	30.07	0.545	5.12	0.35	3102	103.00
	11.00	85	76	315	358	82	230	80	30.07	0.548	5.10	0.40	3608	-
	11.30	86	76	326	374	82	231	80	30.07	0.548	5.10	0.40	4120	106.00
	P. M. 0.00	86	76	337	360	82	232	81	30.07	0.548	5.10	0.40	4547	-
	0.30	89	77	343	370	82	232	81	30.08	0.545	5.12	0.40	4970	106.00
	1.00	88	77	350	384	82	232	81	30.08	0.545	5.12	0.39	5540	102.75
	1.40	85	75	360	380	82	232	81	30.08	0.548	5.10	0.40	6115	-
	2.00	84	74	362	370	83	232	80	30.08	0.544	5.13	0.40	6435	-
	2.30	82	73	370	366	83	232	80	30.08	0.553	5.04	0.40	6860	104.25
	3.00	81	73	372	372	83	232	79	30.08	0.543	5.14	0.40	7355	104.25
	3.30	84	74	378	360	83	230	78	30.08	0.537	5.20	0.35	7857	-
	4.00	81	72	384	318	83	230	77	30.09	0.524	5.33	0.30	8180	-
	A. M.													
Sept. 8	5.30	70	66	216	193	80	213	73	30.13	0.401	6.54	0.10	8194	-
	6.00	70	67	213	190	80	212	72	30.13	0.357	6.98	0.10	8715	-

Period of steady action, from 8*h.* 30*m.* a. m. to 3*h.* p. m.=6*h.* 30*m.* Coal supplied to grate, 829 lbs.; water supplied to boiler, 6,507 lbs.; water to 1 of coal, 7.849.

NEWCASTLE COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet, length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	72.1	114	—25	-	Morning cloudy; wind SW., brisk; commenced firing; water 0.4 inch below normal level.
7.00	73.2	118	+46	-	Wood consumed, 99 lbs.; commenced charging with coal.
-	73.2	108	30	-	Steam blows off; damper set at 8 inches; wind strong, SW.
7.25	71.7	104	92	2.066	This coal ignites quickly.
8.30	71.7	115	128	1.322	
-	71.7	136	136	3.152	
9.07	72.5	159	125	2.580	Filling tank at 9h. 30m. a. m.
9.37	71.0	182	186	2.204	Filled tank at 9h. 35m. a. m.; sun shining; fire in vigorous action.
10.25	71.8	208	120	4.005	Wind NW., brisk; cloudy at 10h. 15m. a. m.
-	73.0	230	128	2.691	
11.15	72.7	240	143	2.713	Smoke 18 seconds in reaching chimney top; syphon 0.37.
-	72.7	251	128	2.262	Considerable smoke from chimney to-day—apparently more than yesterday.
0.05	73.2	254	138	2.241	
1.15	73.5	262	152	3.019	
-	71.5	275	148	2.285	Filled tank at 1h. 45m. p. m.; wind NE., strong; cloudy.
-	70.4	278	138	2.543	
2.05	69.6	288	134	2.251	
3.00	70.0	291	140	2.622	Wind strong from NE.
-	70.4	294	130	2.659	Contents of ash pit thrown on grate; damper reduced to 3 inches.
-	68.4	308	88	1.711	Water left at 0.3 inch above normal level.
-	63.8	146	—20	-	Water in boiler 1.5 inch below normal level.
-	65.4	148	—22	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	32.00
Ashes	30.75
Ashes behind bridge	0.75
Total clinker and ashes	63.50
Deduct wood ashes	0.304
Total waste from coal	63.196
Coke	11.00

TABLE CLXXIII.—

Third trial—upper damper 4 inches open; air plates

Period of steady action, from 8h. 15m. a. m. to 3h. 30m. p. m.—7h. 15m.; coal supplied to the grate, 725.75 lbs.; water to boiler, 4,837 lbs.; water to 1 of coal, 6.664.

NEWCASTLE COAL.

closed; steam allowed to escape from both valves.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	65.4	143	—22	-	Morning cloudy; wind NW., light; commenced firing; water 0.42 inch below normal level.
6.55	64.9	125	+71	-	Wood consumed, 103 lbs.; commenced charging with coal; valves double weighted.
-	64.4	127	90	-	Steam allowed to blow off; damper set at 4 inches.
7.30	64.4	132	65	3.345	Steam allowed to escape from both valves.
8.15	64.0	160	75	1.709	Cloudy; wind NE., light.
-	61.8	190	82	1.335	Sun beginning to shine.
8.55	66.5	222	108	1.677	Wind SW., light; cloudy; filled tank at 9*h.* 35*m.*
-	65.3	245	92	1.989	Fire in small furnace extinct, and its damper closed.
-	66.5	264	99	1.791	Almost calm, cloudy.
10.40	66.5	278	102	2.712	
11.25	68.4	290	100	1.335	
-	67.2	298	108	2.225	Continues cloudy.
0.30	67.2	308	108	1.350	
-	69.6	316	90	1.854	More soot than in the two preceding days accumulates on the thermometer in chimney; clear; wind SE., light.
1.35	69.6	328	94	1.968	
2.30	71.2	328	103	1.748	
-	71.2	338	80	1.828	Smoke from chimney to-day whilst charging and stoking is dense and voluminous; filled tank at 3*h.* 5*m.*
3.30	71.2	344	105	1.271	
-	74.1	347	110	1.801	Contents of ash pit thrown on grate; floor sprinkled with water.
-	69.2	355	90	-	Water in boiler 0.3 inch above normal level.
-	67.5	172	—28	-	Water in boiler 2.35 inches below normal level.
-	68.2	166	—19	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	25.50
Ashes	30.75
Ashes behind bridge	0.69
Total clinker and ashes	56.94
Deduct wood ashes	0.316
Total waste from coal	56.624
Coke	12.50

TABLE CLXXIV.—

Fourth trial—upper damper 8 inches open; air plates open;

Date.	Hour.	Temperatures of the open air entering below ash pit.	Temperatures of the wet bulb thermometer.	Temperatures of the air entering back of grate.	Temperatures of the gas entering chimney.	Temperatures of the water in tank.	Temperatures of the steam in boiler.	Temperatures of the attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Sept. 9	6.10	74	70	240	188	80	207	74	30.09	0.354	7.02	0.12	-	-
	7.04	78	72	213	232	80	228	74	30.09	0.523	5.34	0.21	-	97.75
	7.15	80	73	217	325	80	233	75	30.19	0.545	5.12	0.35	-	-
	8.00	80	71	230	360	80	232	76	30.11	0.545	5.12	0.36	605	103.50
	8.30	80	70	253	400	80	232	77	30.13	0.550	5.07	0.38	940	98.75
	9.00	83	71	280	382	80	232	77	30.13	0.539	5.18	0.36	1350	-
	9.30	82	70	310	408	80	232	78	30.13	0.545	5.12	0.38	1842	104.50
	10.00	81	69	320	434	80	232	79	30.13	0.549	5.08	0.40	2148	-
	10.30	82	69	334	400	78	232	78	30.13	0.553	5.04	0.40	2555	103.25
	11.00	82	68	343	431	78	232	78	30.13	0.552	5.05	0.41	2978	-
	11.30	84	70	352	420	78	232	78	30.13	0.552	5.05	0.41	3406	104.25
	P. M.													
	0.00	82	68	358	423	78	232	77	30.13	0.539	5.18	0.39	3913	104.50
	0.30	83	69	362	414	77	230	77	30.13	0.537	5.20	0.35	4253	-
	1.00	84	70	370	418	78	232	77	30.13	0.537	5.20	0.35	4688	-
	2.00	86	70	378	404	78	232	77	30.14	0.541	5.16	0.35	5518	103.50
	2.30	85	69	383	416	78	232	77	30.14	0.541	5.16	0.33	5838	100.75
	3.00	85	68	387	400	80	231	77	30.14	0.539	5.18	0.32	6398	101.75
	3.30	88	70	406	386	80	230	77	30.15	0.533	5.24	0.30	6739	-
	4.00	86	68	398	392	80	230	77	30.15	0.527	5.30	0.30	7231	-
	A. M.													
Sept. 10	7.50	68	59	216	190	78	215	66	30.27	0.392	6.60	0.15	7251	-
	8.20	70	62	214	190	78	209	67	30.28	0.362	6.94	0.15	7883	-

Period of steady action, from 8*h*. 40*m*. a. m. to 3*h*. p. m.=6*h*. 20*m*. Coal supplied to grate, 722.5 lbs.; water to boiler, same time, 5,322 lbs.; water to 1 of coal, 7.366.

NEWCASTLE COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	68.2	166	—19	-	Morning clear; wind NW., light; commenced firing; water 0.52 inch below normal level.
7.04	69.5	135	+ 4	-	Wood consumed, 117¾ lbs.; commenced charging with coal; valves double weighted.
-	70.3	137	92	-	Steam allowed to escape; double weight removed from valves.
7.30	67.2	160	128	2.134	Air plates opened at 7*h*. 55*m*.
8.40	65.7	173	168	1.775	
-	66.1	197	150	2.172	
9.20	64.9	228	176	2.607	
-	63.7	239	202	1.621	Filled tank at 10*h*. 5*m*.
10.20	63.2	252	168	2.129	
-	61.5	261	202	2.241	
11.10	64.1	268	188	2.268	Smoke 14 seconds in reaching chimney top; syphon 0.39.
0.00	61.5	276	191	2.686	Coal in drying apparatus weighs 27 lbs. 7 oz.
-	62.8	279	184	1.801	Smoke from chimney to-day less voluminous and dark than yesterday.
-	64.1	286	186	2.305	Day clear; wind NW., brisk.
1.10	63.3	292	172	2.199	The coal burned to-day contains much fine.
2.05	62.0	298	184	1.695	Filling tank; water below usual level.
3.00	60.3	302	169	2.967	Filled tank at 2*h*. 40*m*.
-	62.6	318	156	1.806	Air plates closed, and contents of ash pit thrown on grate.
-	59.9	312	162	-	Damper reduced to 3 inches; water 0.7 inch above normal level.
-	52.3	148	—25	-	Water 1.8 inch below normal level; morning overcast; wind NE., light.
-	56.9	144	—19	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	24.00
Ashes - - - - - - - - - - -	31.00
Ashes behind bridge - - - - - - - - - -	0.69
	55.69
Deduct wood ashes - - - - - - - - - -	0.359
Total waste from coal - - - - - - - - -	55.331
Coke - - - - - - - - - - -	13.50
Soot - - - - - - - - - - -	16.25

TABLE CLXXV.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (Table CLXXI.)	2d Trial. (Table CLXXII.)
		September 6.	*September* 7.
1	Total duration of the experiment, in hours	24.667	24.00
2	Duration of steady action, in hours	6.283	6.50
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	9.0	11.0
7	Total weight of coal supplied to grate, in pounds	900.75	1121.0
8	Pounds of coal actually consumed	895.00	1110.0
9	Pounds of coal withdrawn and separated after trial	5 75	11.0
10	Mean weight, in pounds, of one cubic foot of coal	50.041	50.95
11	Pounds of coal supplied per hour, during steady action	110.49	127.53
12	Pounds of coal per square foot of grate surface, per hour	7.852	9.063
13	Total waste, ashes and clinker, from 100 pounds of coal	5.93	5.693
14	Pounds of clinker alone, from 100 pounds of coal	4.8315	2.8692
15	Ratio of clinker to the total waste, per cent.	84.472	50.396
16	Total pounds of water supplied to the boiler	7292.0	8715.0
17	Mean temperature of water, in degrees Fahrenheit	85°.0	82°.7
18	Pounds of water supplied at the end of experiment, to restore level	270.0	521.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds	34,0	67.0
20	Pounds of water evaporated per hour, during steady action	930.28	1001.07
21	Cubic feet of water per hour, during steady action	14.88	16.01
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.465	2.651
23	Pounds of water per square foot, by a mean of several observations	2.469	2.658
24	Water evaporated by one of coal, from initial temp. (a) final result	8.1095	7.791
25	Water evaporated by one of coal, from initial temp. (b) during steady action	8.419	7.849
26	Pounds of fuel evaporating one cubic foot of water	7.707	8.0221
27	Mean temperature of air entering below ash pit, during steady pressure	86°.92	83°.60
28	Mean temperature of wet bulb thermom., during steady pressure	77°.42	74°.87
29	Mean temperature of air, on arriving at the grate	269°.46	301°.80
30	Mean temperature of gases, when arriving at the chimney	318°.23	363°.47
31	Mean temperature of steam in the boiler	230°.38	231°.07
32	Mean temperature of attached thermometer	83°.19	79°.6
33	Mean height of barometer, in inches	30.138	30.074
34	Mean number of volumes of air in manometer	5.098	5.083
35	Mean height of mercury in manometer, in atmospheres	0.5471	0.5490
36	Mean height of water in syphon draught gauge, in inches	0.3377	0.3961
37	Mean temperature of dew point, by calculation	74°.32	71°.80
38	Mean gain of temperature by the air before reaching grate	182°.54	218°.20
39	Mean difference between steam and escaping gases	87°.84	134°.30
40	Water to one of coal, corrected for temperature of water in cistern	8.0749	7.7591
41	Water to one of coal, from 212°, corrected for temperature of water in cistern	9.0706	8.7308
42	Pounds of water, from 212°, to one cubic foot of coal	453.90	444.84
43	Water, from 212°, to 1 lb. of combustible matter of the fuel	9.6424	9.2579
44	Mean pressure, in atmospheres, above a vacuum	1.4538	1.4519
45	Mean pressure, in pounds per square inch, above atmosphere	6.7014	6.6749
46	Condition of the air plates at the furnace bridge	Open.	Closed.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

TABLES CLXXI, CLXXII, CLXXIII, CLXXIV.

Newcastle coal.

3d Trial. (Table CLXXIII.)	4th Trial. (Table CLXXIV.)	Averages.	Remarks.
September 8.	*September* 9.		
24.167	26.167		
7.25	6.333		
14.07	14.07		
377.5	377.5		
18.75	18.75		
10.0	10.0		
1021.5	1022.5		
1009.0	1009.0		
12.5	13 5	10.69	
51.075	51.121	50.772	
100.10	114.08	113.05	
7.113	8.108	8.034	
5.612	5.483	5.6795	
2.5124	2.3637	3.1442	
44.761	43.105	55.6835	
7402.0	7883.0		
79°.1	79°.0		
898.0	632.0		
117.0	83.0		
667.17	840.36	859.72	
10.67	13.44	13.75	
1.767	2.226	2.277	
1.775	2.224		
7.22	7.73	7.7126	
6.664	7.366	7.5745	
8.571	8.0854	8.0964	
80°.07	82°.79		
71°.21	69°.43		
359°.29	332°.84	315°.84	
326°.79	408°.07	354°.14	Omitting the third trial, there is a progressive increase of temperature in the escaping gases, due to the coating on the flues. The 43d line, below, shows that there is also a progressive diminution of evaporative effect in the 1st, 2d, and 4th trials.
230°.64	231°.79		
74°.57	77°.36		
30.121	30.131		
5.17	5.128		
0.5401	0.5442		
0.2728	0.3708	0.3443	
67°.57	63°.60		
279°.22	150°.07	207°.51	
96°.07	180°.0	124°.55	
7.1946	7.7028	7.6828	
8.1243	8.6975	8.6558	
414.95	444.66	439.59	
8.6074	9.202	9.1777	The diminution of effect on the 3d trial, when the damper was drawn but 4 inches, is in accordance with what has been noticed several times before.
1.4201	1.4356	1.4404	
6.2049	6.433	6.5035	
Closed.	Open.		
U. 4	U. 8.		

Remarks on the preceding table of deductions.

With the air plate closed, and damper drawn 8 inches, the rate of evaporation on the second day of trial (September 7th) was 16.01 cubic feet of water per hour, while on the third trial, (September 8th,) with the air plate likewise closed, and the damper drawn only 4 inches, the evaporation was 10.67 cubic feet per hour. The falling off in *rapidity* of evaporation is therefore 33.3 per cent. It appears also that the fuel was burned with less economy on the third than on the second day of trial. Same line (43d) shows the evaporative effect of one of combustible matter to have been 9.2579 on the second, and but 8.6074 on the third. The difference amounts to 7 per cent. of the larger number. The dense smoke which passed out of the chimney on the third trial, (see column of "remarks," table CLXXIII,) indicates the cause of this diminution of useful effect. The slow passage of air towards the grate, retarded as it was by the partly closed damper, caused it to arrive there with a temperature, on the third day's trial, of 359°, instead of 301°, which the air had possessed on the preceding day.

The longer continuance of the products of combustion about the absorbing surfaces of the boiler caused them, on the contrary, to quit the horizontal flue, and pass into the chimney with a mean temperature of only 326°.8, instead of 363°.5, as on the preceding day. From this last remark it appears that we cannot refer the loss of useful effect to the superior temperature of the escaping gases. It must be sought for in the imperfection of the combustion carried on in the furnace, while the smoke was throttled by the damper drawn only 4 inches.

The fourth trial, with damper drawn 8 inches, and the air plate open, was intended as a repetition of the first, and was designed to afford the means of ascertaining what effect the sooty lining of the flues, derived from three days' previous combustion, would produce on the heat-absorbing power of the boiler. That effect is apparent, both in the temperature which the products of combustion carried to the chimney, and in the evaporative power of the unit of combustible matter. They are seen at lines 30 and 43; in the former of which it is shown that the gases reached the chimney during the *first* trial at 318°.23, and during the *fourth* at 408°.07; and in the latter, the evaporative power is found to have been 9.6424 on the first, and but 9.202 on the fourth. The difference (0.4404) is about 4.5 per cent. of the useful effect derived from the fuel when the flues were entirely clean. To know whether the higher temperature of the products of combustion is adequate to account for the lower evaporative efficiency of the combustible matter, it may be assumed that the weight of air equivalent in its capacity to absorb heat to that of the products of combustion from one pound of combustible matter of this coal, was the same as that found on the fourth trial of Liverpool coal, viz: 19.888 pounds. As the gases passed away 89°.84 hotter on the fourth day than on the first, and as the specific heat of air is 0.267, the following computation gives the evaporative power of the heat thus expended, viz: $(19.888 \times 89.84 \times 0.267) \div 1030 = 0.4632$. This proves with sufficient exactness that the cause assigned is amply sufficient to account for the effect observed.

No. 6.

Bituminous coal from Scotland, presented for trial and comparison with American coals, from Messrs. Laing & Randolph, New York.

The exterior app
In some, it is that o
want of lustre, its con
ing the surfaces of d
or shining lustre of b
are completely defin
Carbonate of lime a
numerous little dike
of cannel and foliate
specimen. Hence it
where these characters co-exist. It seems probable that considerable diversity exists in the composition of different plies of the seam or bed from which it was derived.

In some of our Western States, similar diversities in the appearance of coal from the same bed are to be met with.

The specific gravity of one specimen (*a*) was found to be 1.5834; that of another (*b*) was 1.4552. By the mean of these, the calculated weight per cubic foot is 94.955 pounds. Thirty-eight trials in the charge box proved the actual weight to be 51.092 pounds, or 0.538 of the calculated weight. The space for stowing one ton is 43.843 cubic feet. The maximum weight of a cubic foot by trial was 56.375, and the minimum 46.125 pounds. The mean of these two, 51.25, is very near the above average of the whole number of charges.

The moisture found in specimens *a* and *b* was precisely the same, viz: 2.049 per cent. By exposure for four days in the steam-drying bath, 28 pounds of this sample lost 13.5 ounces, or 3.013 per cent.

The sulphur in *b* was 0.3582 per cent.; and the volatile matter, other than moisture, expelled by coking, was 37.281; while that from *a* was 28.311 per cent.

The earthy matter in *a* was 12.325, and that in *b* 14.87 per cent. Hence we have the composition of—

	Specimen *a*.	Specimen *b*.
In moisture	2.049	2.049
In sulphur	(not tried)	0.358
In other volatile matter	28.311	36.923
In earthy matter	12.325	14.870
In fixed carbon	57.315	45.800
	100.	100.
Volatile to fixed combustible	1 : 2.0245	1 : 1.2285

Specimen *b* had an aspect decidedly like that of cannel coal, and was largely interspersed with laminæ of carbonate of lime in the partings. In the incinerations of *b*, (in which portions of the powder were placed in four different platinum cups in the same muffle,) the cup which had been in the hottest part had lost more than any of the rest, and the per centage of residue followed the reverse order of the temperatures to which the cups had

been exposed. The order is that of the following numbers, beginning with that which had been in the hottest part: 13.86, 14.97, 15.10, and 15.39. The complete reduction of carbonaceous matter does not necessarily imply
nposition of the earthy carbonates, for which a very strong
 required. If hydrated argillaceous substances exist in the
s of the coal, they may require a still higher temperature to
ortions of water.
matter, including moisture, obtained from two specimens of
y Dr. King, amounted to 41.85 per cent.
f coal burned during the four trials of evaporative power,
ds. The ashes withdrawn were 175.5, the clinker 220.25,
.375 pounds. When completely reincinerated, the

Ashes lost 13.923 per cent.,	leaving		151.07	pounds	of incombustible	matter.
Clinker " 8.67	"	"	201.15	"	"	"
Soot " 54.67	"	"	11.05	"	"	"
In all	-	-	363.27	"	"	"
From which taking the ashes of 981.25 pounds of wood		=	2.83	"	"	"
Leaves the incombustible matter from the coal alone		=	360.44 pounds=9.3378 per cent.			

From these data may be derived the following composition of the coal of this sample:

Moisture, from 28 pounds - - - -	3.013
Other volatile matter (two specimens) - - -	38.837
Earthy matter, from 3,860 pounds - - -	9.338
Fixed carbon, by difference - - . -	48.812
	100.

Volatile to fixed combustible 1 : 1.2569.

The ashes weighed per cubic foot 47.94, the clinker 39.87, and the soot 8.65 pounds.

The clinker is in general black, with some whitish portions of slate adhering. It was in sheets of considerable magnitude, and produced so much obstruction of the grate, as to require removal once or twice in the course of a day's operations. The slaty portions preserve, in many specimens, the original forms of their masses.

The color of the residue, after reincinerating the pulverized clinker, was a light gray, very slightly bordering on red; of the ashes, dark brown; of the soot, light yellowish gray; while that derived from analysis was of a dark brown, or deep "ashen" gray.

A trial of specimen *b*, with the oxide of lead, yielded 22.7 of lead reduced by 1 of raw coal employed; and, deducting 0.16919 for moisture and ashes, this gives 27.03 of lead to 1 of combustible. Had the whole combustible matter been carbon, its reductive power would have been $0.83981 \times 34 = 28.553$. Hence the actual reductive power was 5.2 per cent. less than it would have been had the whole been carbon, instead of containing a large proportion of hydrogen.

A specimen of the cannel variety was submitted to analysis with the scale oxide of copper. It had a specific gravity of 1.2759;

Possessed of moisture (expelled by heating to 250° for half an hour)	1.365	per cent.
Of other volatile matter	35.586	"
Of earthy matter	2.707	"
Of fixed carbon	60.342	"
	100.	

And having, therefore, the fixed to the volatile combustible in the ratio of 1.6957 to 1.

Of this specimen, dried in fine powder as above, were taken 7.64 grains; of which the earthy matter was 0.2097 grain, and the combustible part was, consequently, 7.4303 grains. Submitted to analysis with all the usual precautions, this gave of carbonic acid 22.6, and of water 3.75 grains. Admitting 6 to be the atomic weight of carbon, this gives—

Carbon	6.1636	grains.
Hydrogen	0.4166	"
Of which the sum =	6.5802	"
And this deducted from	7.4303	"
Leaves of oxygen and azote	0.8501	"

As 7.64 grains of dried coal are equivalent to 7.7457 grains in the raw state, the above data afford the following as the ultimate constitution of this specimen in that condition, viz:

Moisture	1.365
Carbon	79.574
Hydrogen	5.378
Oxygen and azote	10.976
Ashes	2.707
	100.

If the moisture and ashes be deducted, the relation of the remaining constituents to each other is—

Carbon	82.952 =	13.825	atoms.
Hydrogen	5.607 =	5.607	"
Oxygen, &c.	11.441 =	1.430	"
	100.		

As the above analysis shows the total carbon in the raw coal to be 79.574 per cent., and the previous trial had given the fixed carbon equal to 60.342, it is evident that the difference (19.232) must have been the

portion volatilized in the process of coking; so that the volatile matter must have consisted of—

Carbon	- -	19.232
Hydrogen	- -	5.378
Oxygen and azote	-	10.976
		In 35.586 parts obtained in the first analysis.

One-eighth of the oxygen in the raw coal is 1.372 grain; which deducted from the hydrogen, (5.378,) leaves 4.006. Hence, to compute the heating power of the raw coal by Despretz's numbers, we have—

For the hydrogen - -	$0.04006 \times 42552 =$	1704.6
For the carbon - -	$0.79574 \times 14040 =$	11172.0
The sum of these - -	$=$	12876.6

And this, divided by the degrees expressing the latent heat of the vapor of water, (1030°,) gives 12.501 pounds of water which ought to have been evaporated from 212° by one pound of the raw coal, on the supposition that the whole heating power had been employed in producing that effect; whereas the maximum effect of one pound of the coal burned under the steam boiler was but 7.476, and the average of four trials only 6.946 pounds of steam generated from that temperature.

By adopting the numbers of Dulong, we have—

The heating power of the hydrogen	$0.04006 \times 62535 =$	2505
" " carbon	$0.79574 \times 12906 =$	10270
Or the total heating power is - -		12775

This shows still a wide departure from the practical result. Expressed in evaporative efficiency, it amounts to 12.402, instead of 12.501, as above.

By reference to the table exhibiting the analyses of gases drawn from the chimney, it will be seen that three trials on that subject were made while burning the Scotch coal; and under the title of *deductions relative to the heating power of fuel*, in the same table, will be found the evaporative power of the heat employed on all the absorbents; that is, on the escaping gases, the water from combustion, the hygrometric moisture of the air, and the water in the boiler. The average number is 8.464, and the maximum 8.868. These numbers would be increased to 9.7412 and 10.206, by computing for *one of combustible* in the coal burned; that is, after deducting 3.013 for moisture, and 10.098 for mean amount of waste left after the fire was extinct.

The heating power of one of combustible in the *analysis*, is found, in like manner, by deducting the moisture and ashes found in the specimen assayed, and dividing by the remainder the numbers already given. Thus, $1-0.04072=0.95928$; and $12876 \div 0.95928=13423$, by the numbers of Despretz; $12775 \div 0.95928=13317$, by those of Dulong.

If from the mean of these (13370) be deduced the evaporative power, it amounts to 12.98; from which taking 10.206, the remainder (2.774) will be 23.665 per cent. of that mean. We cannot suppose this deficiency to have been due to the carbon wasted in the smoke, since the amount of

volatilizable carbon altogether is but 19.232 per cent. of the coal, or 20.048 per cent. of the combustible matter.

From the proportion of the three *combustible ingredients* already presented, the separate calorific and evaporative powers of the carbon and hydrogen are deduced, as follows, from the numbers given by Dulong: $(0.82952 \times 12906) \div 1030 = 10.393$ of steam from the carbon in 1 of combustible; and $(0.04177 \times 62535) \div 1030 = 2.535$ of steam from the hydrogen in 1 of combustible. And as we have obtained, by experiment in the large way, 10.206 of steam power from 1 of combustible, it should seem (if Dulong's number can be relied on) that the *weight of carbon* in this coal is the measure of its heating power.

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TABLE CLXXVI.—

First trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	Temperatures of the							Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
		Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.						
	h. m.													
	A. M.													
Aug. 19	4.40	77	72	122	98	78	98	78	30.01	0.348	7.07	0.04	–	–
	7.00	79	74	128	212	78	160	78	30.02	0.350	7.05	0.15	–	–
	8.20	81	76	168	243	78	230	80	30.01	0.527	5.30	0.20	–	94.00
	9.00	79	75	188	264	78	232	81	30.01	0.585	5.22	0.25	404	97.25
	9.30	84	76	205	282	79	232	82	30.01	0.533	5.24	0.26	828	95.25
	10.00	85	77	237	283	79	232	83	30.01	0.536	5.21	0.28	1328	97.00
	10.30	86	77	264	282	79	232	84	30.01	0.541	5.16	0.28	1828	98.75
	11.00	88	78	278	296	79	232	85	30.01	0.536	5.21	0.29	2346	97.00
	11.30	88	78	292	301	79	232	86	30.02	0.540	5.17	0.30	2855	101.25
	P. M.													
	0.00	91	79	308	304	80	232	87	30.01	0.529	5.28	0.28	3484	101.75
	0.30	90	78	308	–	80	232	89	30.00	0.537	5.20	0.30	4055	–
	1.00	91	79	322	296	80	232	89	30.00	0.535	5.22	0.29	4560	103.00
	1.30	91	79	326	296	80	232	89	29.96	0.526	5.30	0.24	4970	–
	2.00	92	80	331	278	80	231	89	29.97	0.515	5.42	0.20	5207	–
	2.30	83	76	334	266	81	231	88	29.97	0.515	5.42	0.16	5530	–
	4.20	84	77	274	232	81	227	83	29.94	0.492	5.64	0.13	5620	–
	A. M.													
Aug. 20	8.30	77.5	74	164	182	80	202	77	29.94	0.347	7.08	0.08	5625	–
	9.00	77.5	74	156	170	80	200	78	29.94	0.347	7.08	0.08	5684	–

Period of steady action, from 8*h.* 45*m.* a. m. to 0*h.* 45*m.* p. m.—4*h.*; coal supplied to the grate in that time, 694 lbs.; water supplied to boiler, 4,106 lbs.; water to 1 of coal, 5.942.

SCOTCH COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	69.9	45	± 0	-	Morning clear; wind NE., light; commenced firing at 5h. a. m.
-	72.1	49	+52		
8.20	72.4	87	13	-	Commenced charging with coal; wood consumed, 468 lbs.
8.45	73.5	109	32	2.140	Steam blowing off at 8h. 30m. a. m.; damper reduced to 8 inches at 9h. a. m.
9.25	73.3	121	50	2.219	
9.50	74.4	152	51	2.649	
10.20	74.1	178	50	2.638	Placed 28 lbs. of this coal in drying apparatus.
11.00	74.9	190	64	2.755	Smoke 18 seconds in reaching chimney top; syphon 0.30.
11.35	74.9	204	69	2.697	Filled tank at 11h. 56m. a. m.
0.10	75.5	217	72	3.306	Commenced drawing gases from lower flue at 0h. 11m. p. m.; drew in 22 minutes 100 cubic inches, which gave
-	74.4	218	-	3.025	water 1 grain, carbonic acid 5.34 grains, oxygen 12.5
0.45	75.5	231	64	2.675	cubic inches. Contents of ash pit thrown on grate at 1h. p. m.
-	75.5	235	64	2.172	Fire declining rapidly; clinker spreads over the grate.
-	76.6	239	47	1.256	
-	73.6	251	35	1.711	Commenced raining; wind SE.
-	74.7	190	—5	-	Water at normal level; raining.
-	72.6	86.5	—20	-	Water 0.6 inch below normal level; wind NE.; cloudy; violent rain last night; at 7h. 45m. a. m., water in boiler adjusted.
-	72.6	78.5	—30		

RESIDUA.

	Pounds.
Clinker	40.75
Ashes	28.00
Ashes behind bridge	1.30
Total clinker and ashes	70.05
Deduct wood ashes	1.421
Total waste from coal	68.629
Coke	3.50

TABLE CLXXVII.—

Second trial—upper damper 8 inches open; air plates open;

SCOTCH COAL.

steam thrown into chimney, and small furnace in action.

RESIDUE.	Pounds.
Clinker - - - - - - - - - -	51.25
Ashes - - - - - - - - - - -	42.50
Ashes behind bridge - - - - - - - - -	1.40
Total clinker and ashes - - - - - - - -	95.15
Deduct wood ashes - - - - - - - -	0.720
Total waste from coal - - - - - - - - -	94.430
Coke - - - - - - - - - - -	0.75

TABLE CLXXVIII.—

Third trial—upper damper 4 inches open; air plates closed;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Aug. 22	5.55	74	70	170	188	76	206	74	30.03	0.350	7.05	0.10	-	-
	7.20	73.5	70	160	236	77	229	72	30.04	0.523	5.33	0.20	-	104.25
	7.30	74	70	160	242	77	230	73	30.03	0.525	5.32	0.22	-	-
	8.00	74	70	168	303	77	230	72	30.03	0.547	5.10	0.30	165	102.00
	8.30	76	71	173	285	77	231	73	30.03	0.539	5.18	0.30	585	101.25
	9.00	76	71	184	307	77	232	73	30.03	0.545	5.12	0.31	927	-
	9.30	78	72	203	306	76	232	73	30.03	0.539	5.18	0.30	1400	103.50
	10.00	78	72	214	320	76	232	74	30.03	0.539	5 18	0.30	1820	104.25
	10.30	78.5	72	228	300	76	232	74	30.03	0.544	5.13	0.30	2161	-
	11.00	80	72.5	244	312	76	232	75	30.03	0.544	5.13	0.29	2585	103.50
	11.30	80	73	260	316	76	232	76	30.05	0.546	5.11	0.24	3010	99.50
	P. M.													
	0.00	82	74	274	328	76	233	77	30.04	0.535	5.22	0.32	3432	-
	0.30	82.5	74.5	286	312	76	231	77	30.03	0.536	5.21	0.29	3860	112.75
	1.30	83	74	312	310	76	232	77	30.04	0.536	5.21	0.30	4350	106.25
	2.00	85	75	322	318	76	231	78	30.03	0.541	5.16	0.30	4857	116.75
	2.30	84	74	324	306	76	232	78	30.03	0.529	5.28	0.27	5200	-
	3.00	83	75	333	288	76	231	78	30.02	0.529	5.28	0.25	5370	-
	3.30	81	73.5	331	268	76	229	78	30.02	0.517	5.40	0.22	5595	-
	A. M.													
Aug. 23	5.20	76.5	71	192	184	76	214	73	30.05	0.360	6.95	0.12	5600	-
	5.50	76.5	71	187	183	76	209	72	30.05	0.354	7.01	0.11	6042	-

Period of steady action, from 8*h.* 30*m.* a. m. to 2*h.* 0*m.* p. m. = 5*h.* 30*m.*; coal supplied to grate in that time, 740.5 pounds; water to boiler, 4,372 pounds; water to one of coal, 5.769.

SCOTCH COAL.

steam thrown into chimney, and small furnace in action.

...ARKS.—Grate surface 14.07 square feet; length of ...cuit of heated gases 121 feet; height of chimney 66 ...t.

...ing cloudy; wind NW., light; commenced firing; ...r 0.4 inch above normal level.
...l consumed, 102¾ lbs.; commenced charging with coal.
...r blowing off.

...er reduced to 4 inches.

... tank.

... tank at 6h. 46m.
...day continues cloudy; wind NW., brisk.

...nts of ash pit thrown on grate.
...declines rapidly.
...r in boiler left at 0.3 inch above normal level.

...r in boiler 0.06 inch below normal level.
...r in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	63.26
Ashes	46.00
Ashes behind bridge	1.70
	110.96
Deduct wood ashes	0.313
Total waste of coal	110.627
Coke	7.36

TABLE CLXXIX.—

Fourth trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	TEMPERATURES OF THE — Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m.													
	A. M.													
Aug. 23	5.50	73.5	71	187	183	76	200	72	30.05	0.354	7.01	0.11	–	–
	7.00	74	[illegible]	176	266	76	230	71	30.05	0.523	5.33	0.30	–	100.00
	7.40	74.5	69	182	323	76	233	71	30.05	0.546	5.11	0.31	260	99.25
	8.00	76	70	186	330	76	233	72	30.05	0.547	5.10	0.33	520	100.50
	8.30	76	70	202	342	76	233	72	30.05	0.551	5.06	0.35	946	102.25
	9.15	78	70	228	296	75	233	73	30.06	0.541	5.16	0.30	1492	103.50
	10.00	80	71	258	314	75	232	74	30.06	0.549	5.08	0.34	2141	104.75
	10.30	80.5	71.5	267	344	75	232	75	30.05	0.539	5.18	0.33	2628	105.25
	11.15	83	73	276	344	75	233	76	30.07	0.539	5.18	0.26	3232	105.50
	P. M.													
	0.00	85	74	295	328	76	233	76	30.06	0.531	5.26	0.32	3919	106.50
	0.30	84	73	298	371	75	232	77	30.06	0.543	5.14	0.31	4334	–
	1.00	84	74	308	388	78	232	77	30.06	0.536	5.20	0.35	4767	107.75
	1.30	84.5	73	311	366	78	233	78	30.06	0.536	5.20	0.30	4984	–
	2.15	85	74	326	319	78	232	79	30.04	0.519	5.38	0.33	5464	–
	3.15	81	71	312	363	78	230	79	30.02	0.507	5.50	0.30	5582	–
	A. M.													
Aug. 24	6.20	69	67	182	182	78	216	72	30.04	0.381	6.74	0.12	5587	–
	6.45	71	67	177	178	79	210	72	30.04	0.353	7.02	0.12	6017	–

Period of steady action, from 7*h*. 55*m*. a. m. to 1*h*. 5*m*. p. m.=5*h*. 10*m*. Coal supplied to grate in that time, 738.5 lbs.; water to boiler, 4,420 lbs.; water to 1 of coal, 5.985.

SCOTCH COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature betw'n steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate-surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 69 feet.
h. m.					
–	[illegible]	110.5	—26	–	Morning cloudy, wind NW., light; commenced firing; water 0.6 inch above normal level.
7.00	66.6	102	+38	–	Wood consumed, 119 lbs.; commenced charging with coal.
7.30	66.4	107.5	[illegible]	1.083	Steam blows off at 7*h.* 10*m.* a. m.
7.55	67.3	110	97	2.066	
8.30	67.3	126	109	2.257	
9.15	66.5	150	63	1.898	Filled tank at 9*h.* 4*m.* a. m.
10.00	67.2	178	82	2.329	
10.50	67.6	186.5	112	2.633	
11.37	69.2	193	111	2.098	
0.00	70.0	210	95	2.426	
–	68.9	214	139	2.199	
1.05	70.4	224	155	2.294	
–	68.9	226.5	133	1.149	Filled tank; contents of ash pit thrown on grate.
–	70.0	235	78	1.695	Damper reduced to 4 inches.
–	66.9	231	133	–	Water in boiler left at 0.15 inch above normal level; wind SE.; cloudy.
–	66.0	113	—34	–	Water in boiler 0.8 inch below normal level.
–	64.9	106	—32	–	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	65.00
Ashes - - - - - - - - - - -	53.00
Ashes behind bridge - - - - - - - - -	1.60
Total clinker and ashes - - - - - - - -	119.60
Deduct wood ashes - - - - - - - - -	0.362
Total waste from coal - - - - - - - -	119.238
Coke - - - - - - - - - - -	5.50
Soot - - - - - - - - - - -	24.375

TABLE CLXXX.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. (Tab. CLXXVI.)	2d Trial. (Tab. CLXXVII.)
		August 19.	*August* 21.
1	Total duration of the experiment, in hours - - -	28.333	23.833
2	Duration of steady action, in hours - - - -	4.00	4.583
3	Area of grate, in square feet - - - -	14.07	14.07
4	Area of heated surface of boiler, in square feet - -	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet -	18.75	18.75
6	Number of charges of coal supplied to grate - - -	9.0	9.0
7	Total weight of coal supplied to grate, in pounds - -	885.25	911.5
8	Pounds of coal actually consumed - - - -	881.75	904.75
9	Pounds of coal withdrawn and separated after trial - -	3.5	6.75
10	Mean weight, in pounds, of one cubic foot of coal - -	49.181	50.638
11	Pounds of coal supplied per hour, during steady action -	173.5	154.09
12	Pounds of coal per square foot of grate surface, per hour -	12.33	10.905
13	Total waste, ashes and clinker, from 100 pounds of coal -	7.783	10.436
14	Pounds of clinker alone, from 100 pounds of coal - -	4.5692	5.6204
15	Ratio of clinker to the total waste, per cent. - - -	58.197	53.856
16	Total pounds of water supplied to the boiler - - -	5884.0	5873.0
17	Mean temperature of water, in degrees Fahrenheit - -	79°.4	76°.0
18	Pounds of water supplied at the end of experiment, to restore level - - - - - - - -	259.0	345.0
19	Deduction for temperature of water supplied at the end of experiment, in pounds - - - - - -	33.0	45.0
20	Pounds of water evaporated per hour, during steady action -	1026.25	923.13
21	Cubic feet of water per hour, during steady action - -	16.419	14.769
22	Pounds of water per square foot of heated surface per hour, by one calculation - - - - - -	2.718	2.445
23	Pounds of water per square foot, by a mean of several observations - - - - - - - -	2.745	2.4205
24	Water evaporated by 1 of coal, from initial temperature (a) final result - - - - - - -	6.6356	6.4747
25	Water evaporated by 1 of coal, from initial temperature (b) during steady action - - - - - -	5.915	5.991
26	Pounds of fuel evaporating one cubic foot of water - -	9.4189	9.653
27	Mean temperature of air entering below ash pit, during steady pressure - - - - - - - -	86°.89	79°.18
28	Mean temperature of wet bulb thermom., during steady pressure	77°.44	72°.55
29	Mean temperature of air, on arriving at the grate - -	266°.89	200°.45
30	Mean temperature of gases, when arriving at the chimney -	288°.5	317°.27
31	Mean temperature of steam in the boiler - - -	232°.0	232°.26
32	Mean temperature of attached thermometer - - -	85°.11	75°.82
33	Mean height of barometer, in inches - - -	30.009	30.057
34	Mean number of volumes of air in manometer - -	5.212	5.1445
35	Mean height of mercury in manometer, in atmospheres -	0.5958	0.542
36	Mean height of water in syphon draught gauge, in inches -	0.2862	0.2968
37	Mean temperature of dew point, by calculation - -	74°.5	69°.93
38	Mean gain of temperature by the air, before reaching grate -	180°.0	121°.27
39	Mean difference between steam and escaping gases - -	60°.5	90°.0
40	Water to 1 of coal, corrected for temperature of water in cistern - - - - - - - - -	6.6123	6.4537
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern - - - - - - -	7.4763	7.3059
42	Pounds of water, from 212°, to 1 cubic foot of coal - -	367.2	369.95
43	Water, from 212°, to 1 pound of combustible matter of the fuel	8.0964	8.1571
44	Mean pressure, in atmospheres, above a vacuum - -	1.4255	1.4290
45	Mean pressure, in pounds per square inch, above atmosphere	6.2844	6.3364
46	Condition of the air plates at the furnace bridge - -	Closed.	Open.
47	Inches opening of damper, (U. upper) - - -	U. 8	U. 8

TABLES CLXXVI, CLXXVII, CLXXVIII, CLXXIX.

Scotch coal.

3d Trial. (Tab. CLXXVIII.)	4th Trial. (Tab. CLXXIX.)	Averages.	Remarks.
August 22.	*August* 23.		
23.917	24.917		
5.5	5.167		
14.07	14.07		
377.5	377.5		
18.75	18.75		
10.0	10.0		
1048.0	1038.25		
1040.75	1032.75		
7.25	5.5	5.75	
52.4	51.9125	51.0325	
134.63	142.95	151.2925	
9.581	10.16	10.739	
10.63	11.545	10.0985	
6.062	6.2745	5.6315	
57.025	54.348	55.856	The high proportion of clinker renders this coal very inconvenient for use under the steam boiler.
6042.0	6017.0		
76°.2	76°.0		
442.0	430.0		
58.0	56.0		
776.72	855.59	895.422	
12.42	13.687	14.324	
2.057	2.266	2.394	
2.1336	2.266		
5.7497	5.7719	6.158	By burning this coal with the damper drawn only four inches, a considerable reduction in evaporative power appears in the column of the third trial.
5 769	5.985	5.915	
10.8702	10.8283	10.1926	
79°.42	80°.05		
72°.58	71°.68		
239°.0	255°.55	240°.472	
309°.75	340°.55	314°.02	
231°.67	232°.73		
74°.83	74°.64		
30.033	30.057		
5.161	5.152		
0.5409	0.5416		
0.295	0.3062	0.2965	
69°.91	68°.16		
189°.58	175°.5	159°.19	
91°.0	108°.25	84°.94	
5.7311	5.7532	6.1376	
6.4878	6.5129	6.9457	
339.96	338.1	353.802	
7.2595	7.3629	7.7189	
1.422	1.4248	1.4255	
6.241	6.2737	6.2839	
Closed. U. 4	Closed. U. 8		

No. 7.

Bituminous coal from Pittsburg, Pennsylvania, sent for trial by Messrs. W. T. Hepp & Co., of New Orleans.

The following letter relates to this sample:

"New Orleans, *July* 12, 1842.

"*To the United States Navy Agents; Washington city, D. C.:*

"Gents: We take the liberty of forwarding a bill of lading for one cask *Pittsburg* coal, as a sample, which we believe you will find to be a superior article. In this city it is preferred to any *foreign* coal yet introduced in our country, and superior to any other American bituminous coal as yet discovered. The article has been fully tested by the steamers running from this port to Havana and Texas.

"We propose furnishing the Government with any quantity she may require at this place for $6 50 per ton, or at Pensacola at $9 per ton. Should you require any further information, we shall be happy to receive any communication on that subject from you.

"In the mean time, please acknowledge receipt of the cask of coal, and your opinion thereon.

"We are, very respectfully, your obedient servants,

"W. T. HEPP & Co."

The above letter was not received until after the experiments had been completed, and then as a duplicate in answer to an inquiry made relative to the origin of the coal. The sample consisted of about two hundred weight—scarcely enough for a bare trial under the steam boiler; and certainly not enough for a full development of its properties.

In external characters, it is an almost exact counterpart of the Newcastle coal of England. It has the same resinous lustre, the same exhibition of fossil remains and carbonaceous matter in the surfaces of deposition, the same position of the main partings at right angles to the surfaces just mentioned, and, of course, the same tendency to break into cubical masses. It exhibits less earthy matter in the partings, and seldom shows any trace of pyrites on the surface. Other resemblances will be observable in the following description of analyses and tests to which it was subjected.

The specific gravity of one specimen (*a*) was 1.23, that of another (*b*) 1.2747; the mean of which affords the calculated weight per cubic foot 78.275 pounds. Two trials only could be made in the charge box, the mean of which affords the weight per cubic foot 46.8125, or 0.598 of the calculated weight. The calculated space for the stowage of a ton is 47.85 cubic feet. The moisture found in the two specimens was exactly the same in amount, being 1.397 per cent. Of volatile matter other than water, *a* gave 32.783, and *b* 30.293 per cent.

The sulphur in *b* was 0.1598 per cent.

Five trials by Dr. King gave a mean result in volatile matter of 38 per cent. These were all conducted on the plan of rapid coking, and gave, doubtless, higher proportions of volatile matter than if the process had been carried on more gradually.

In specimen *a*, the earthy matter by four trials was 4.17, and in *b* by eight trials it was 3.26 per cent. The composition of these specimens may, therefore, be stated as follows:

	Specimen *a*.	Specimen *b*.
The moisture was - - - -	1.397	1.397
sulphur - - - -	(not tried)	0.160
other volatile matter - - -	32.783	30.133
earthy matter - - - -	4.170	3.260
fixed carbon - - - -	61.650	65.050
	100.	100.
Volatile to fixed combustible - -	1 : 1.8805	1 : 2.1473
And the mean of these two is - -	1 : 2.0139	

During the single brief experiment on evaporative power, the weight of coal consumed was 208.38 pounds; the ashes derived from it 15.5, and the clinker 2 pounds, while the soot from the flues was 1.75 pound.

The ashes lost by reincineration - - -	21.123 per cent.
The clinker - - - - - -	13.240 "
The soot - - - - - - -	37.650 "

Making these reductions, and deducting 0.311 pound of wood ashes from 101.5 pounds of wood used in commencing the experiment, there remain 14.741 pounds of incombustible matter, which, divided by 208.38, gives 7.0741 per cent.; which shows that the earthy matter in the specimens above analyzed was but about half as much as the average of the sample.

The ashes from the analyses of this coal were of a grayish or yellowish-white color; the pulverized and reincinerated clinker was of a slightly red or reddish-gray color; the residue of the ashes was nearly of the same tint, after a like treatment; and the soot gave a light drab or dirty white residuum. There appeared very little tendency in any of the specimens of clinker to vitrification, or the formation of coherent masses.

This coal ignites quickly and burns freely; it swells but little, and produces a coke moderately coherent.

Two trials on specimen *b* were made with the oxide of lead, resulting in giving for the first 27.870, and for the second 27.215 parts of lead reduced to one of coal employed.

Deducting 0.01397 for moisture, and 0.036 for ashes, the combustible is 0.95343; by which dividing the mean of the above two weights of lead, the result is 28.887.

The sample did not afford a sufficient quantity for trial either in the smith's fires, or in grates for domestic purposes.

TABLE CLXXXI.—PITTSBURG

Upper damper 8 *inches open; air plates closed; steam*

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Weight of charges of coal.
	h. m. A. M.										
Nov. 9	10.05	42.5	40	197	177	40	214	41	30.27	0.3	-
	10.50	48	43	176	238	40	232	42	30.27	0.5	-
	11.30	47	41	174	250	40	232	44	30.25	0.5	92.25
	11.45	50	43	181	267	40	232	45	[illegible]	0.5	95.00
	P. M. 0.00	50	43	188	290	40	232	46	30.22	0.5	31.00
	0.20	50	43	204	295	40	233	46.5	30.21	0.5	-
	0.30	50	43	206	300	40	232.5	47	30.21	0.5	-
	0.45	49.5	42.5	210	288	40	232.5	47	30.20	0.5	-
	1.00	49.5	42	217	259	40	231	47.5	30.19	0.5	-
	1.15	49.5	42	224	248	40	232	48	30.18	0.5	-
	1.30	50	43	227	242	40	232	48	30.19	0.5	-
	2.15	49.5	42.5	231	223	40	233	48	30.16	0.5	-

The boiler can scarcely be considered as having been brought to a condition of steady action before the sample was exhausted; but from 11*h.* 40*m.* a. m., when the second charge of coal was placed on the grate, to 0*h.* 45*m.* p. m., when the combustion appeared to be declining, is 1*h.* 5*m.*; during which, the evaporation was at the rate of 10.56 cubic feet of water per hour.

(PENNSYLVANIA) COAL.

thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 68 feet.
h. m.					
-	34.4	154.5	—37	-	Morning hazy; wind SW., light; commenced firing; water 0.5 inch below normal level.
-	33.5	128	+ 6	-	Wood consumed, 100½ pounds; commenced charging with coal.
10.55	27.9	127	18	-	Steam blows off at 11*h.* 1*m.*; water one inch below normal level; filling tank.
11.40	29.5	131	35	2.238	Water brought to normal level; steam allowed to escape from both valves.
11.54	29.5	138	48	1.716	
-	29.5	154	62	1.971	Back valve weighted down at 0*h.* 12*m.*
-	29.5	156	67.5	1.319	
-	28.5	160.5	55.5	1.610	Damper reduced to 4 inches.
-	26.8	167.5	28	0.985	
-	26.8	174.5	16	-	} Valves double weighted.
-	29.5	177	10	0.4346	} Valves double weighted.
-	28.5	181.5	—10	0.185	Water in boiler adjusted. Observations continued till the safety valve closed, and pressure, by manometer, did not rise when it was double weighted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - - -	2.00
Ashes - - - - - - - - - - -	14.75
Ashes behind bridge - - - - - - - -	0.75
	17.50
Deduct wood ashes - - - - - - - - -	0.311
Total waste from coal - - - - - - - -	17.189
Coke - - - - - - - - - - -	9.875
Soot - - - - - - - - - - -	1.75

TABLE CLXXXII.—DEDUCTIONS FROM TABLE CLXXXI.

Experiment on Pittsburg (Pennsylvania) coal.

	Nature of the data furnished by the preceding table.	Trial. (*T. CLXXXI.*)
		November 9.
1	Total duration of the experiment, in hours	4.167
2	Duration of steady action, in hours	1.083
3	Area of grate, in square feet	14.07
4	Area of heated surface of boiler, in square feet	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75
6	Number of charges of coal supplied to grate	2.333
7	Total weight of coal supplied to grate, in pounds	218.25
8	Pounds of coal actually consumed	208.38
9	Pounds of coal withdrawn and separated after trial	9.87
10	Mean weight, in pounds, of one cubic foot of coal	46.812
11	Pounds of coal supplied per hour, during steady action	00.00*
12	Pounds of coal per square foot of grate surface, per hour	00.00*
13	Total waste, ashes and clinker, from 100 pounds of coal	8.253
14	Pounds of clinker alone, from 100 pounds of coal	0.9406
15	Ratio of clinker to the total waste, per cent.	11.403
16	Total pounds of water supplied to the boiler	1465.0
17	Mean temperature of water, in degrees Fahrenheit	40°.0
18	Pounds of water supplied at the end of experiment, to restore level	00.00†
19	Deduction for temperature of water supplied at end of experiment, in pounds	00.00†
20	Pounds of water evaporated per hour, during steady action	660.02
21	Cubic feet of water per hour, during steady action	10.56
22	Pounds of water per square foot of heated surface per hour, by one calculation	1.7484
23	Pounds of water per square foot, by a mean of several observations	1.7708
24	Water evaporated by one of coal, from initial temperature (a) final result	7.0304
25	Water evaporated by one of coal, from initial temp. (b) during steady action	00.00‡
26	Pounds of fuel evaporating one cubic foot of water	8.890
27	Mean temperature of air entering below ash pit, during steady pressure	49°.5
28	Mean temperature of wet bulb thermometer, during steady pressure	42°.5
29	Mean temperature of air, on arriving at the grate	206°.2
30	Mean temperature of gases, when arriving at the chimney	265°.2
31	Mean temperature of steam in the boiler	232°.2
32	Mean temperature of attached thermometer	46°.7
33	Mean height of barometer, in inches	30.204
34	Mean number of volumes of air in manometer	4.903
35	Mean height of mercury in manometer, in atmospheres	0.5675
36	Mean height of water in syphon draught gauge, in inches	0.334
37	Mean temperature of dew point, by calculation	28°.6
38	Mean gain of temperature by the air, before reaching grate	156°.7
39	Mean difference between steam and escaping gases	53°.6
40	Water to 1 of coal, corrected for temperature of water in cistern and boiler	7.0304
41	Water to 1 of coal, from 212°, corrected for temp. of water in cistern and boiler	8.2044
42	Pounds of water, from 212°, to one cubic foot of coal	384.07
43	Water, from 212°, to one pound of combustible matter of the fuel	8.9424
44	Mean pressure, in atmospheres, above a vacuum	1.4478
45	Mean pressure, in pounds per square inch, above atmosphere	6.6137
46	Condition of the air plates at the furnace bridge	Closed.
47	Inches opening of damper	Upper 8.

* No period of steady action in combustion having been satisfactorily made out, owing to the smallness of the sample, the 11th and 12th deductions are necessarily omitted.

† The experiment was watched constantly until the valve was seated, and the level of water in the boiler adjusted at the moment the steam ceased to escape; hence no deduction for water to restore level is required.

‡ This line cannot be filled, for reasons already stated.

No. 8.

Bituminous coal from Cannelton, Indiana, sent for trial by James Boyd, Esq., of Boston.

The following letter from the agent of Mr. Boyd accompanied one package of this sample of coal:

"LOUISVIL

"SIR: By direction of Mr. James Boyd, I have to-da by steamboat Orpheus, and via Wheeling, National r box of coal from Cannelton, Indiana. The object, as I by analysis the department may test its value as a fue I send herewith the published character of the American Cannel Coal Company, in which you will find Dr. Jackson's analysis of the coal. Dr. F. Hall, of Washington, has recently examined the banks, &c., and has, I learn, expressed very favorable opinions of it in a letter to Francis Markoe, Esq., which will probably be published, and to which I would call your attention.

"From an experiment recently made on the steamer Messenger, (the results of which can be authenticated and forwarded, if desired,) I consider these facts as proven: that even on ordinary grate bars, this coal can be used without wood, and will generate steam more rapidly than the best ash or beach wood; that it does not injure the boilers as much, or the furnace more than wood. As to economy, safety, and convenience, &c., there can be no comparison.

"Very respectfully, your obedient servant,

"HAMILTON SMITH,

"*One of the proprietors of the A. C. Coal Company.*

"The Hon. SECRETARY OF THE NAVY, *&c.*"

The exterior characters of this coal are a *color* deep black; a lustre shining, dull, or resinous, according as the main partings, the horizontal seams, or the cross cleats, are observed. The *fracture* is often conchoidal, and the lustre dull, like that of Scotch cannel coal. The main partings are at angles of 86° and 94° to the surfaces of deposition—such, at least, were the inclinations in several specimens which I measured. The surfaces are frequently covered with films of sulphuret of iron. The powder, like that of most other highly bituminous coals, is distinctly brown; and the more so, the more minute the subdivision. Perfect anthracite is of a deep black, and pure bitumen is scarcely darker in color than burnt sienna. From these limits there is a gradual shading off towards the opposite extreme, according to the greater or less degree of bituminousness of the coal. The streak left on white earthenware is also distinctly brown; it has little or no tendency to soil when rubbed with the finger.

The specific gravity of one specimen of this sample (a) was 1.2479, that of another (b) 1.2975, and the mean of these affords the calculated weight per cubic foot 79.545 pounds; while 26 trials in the charge box gave the least weight 45.5, the greatest 55.25, and the average of the whole 47.649. This shows the actual weight to be 0.5986 of the calculated weight, from taking the specific gravity.

The *moisture*, in a pulverized specimen derived from 40 fragments, from different lumps of this sample, was 2.597 per cent; that of specimens a and

b was not separately ascertained. Twenty-eight pounds, dried in the steam apparatus, gave of moisture 0.893 per cent.

The volatile matter, including moisture, in *a* was 38.157 by a moderate rate of coking; and that in *b*, by the same treatment, 31.513.

Specimen *a* gave of rather heavy yellowish white ash, 3.498 per cent., and *b* of similarly colored residue 8.165. Hence the composition may, without material error, be assumed as follows, viz:

	Specimen *a*.	Specimen *b*.
Moisture, from 40 specimens - - - -	2.597	2.597
Other volatile matter - - - -	35.560	28.916
Earthy matter - - - - -	3.498	8.165
Fixed carbon - - - - -	58.345	60.322
	100.	100.
Volatile to fixed combustible - -	1 : 1.6407	1 : 2.086

Of the above specimen of powder from 40 lumps of the coal, 71.48 grains gave of white ashes 2.73 grains=3.819 per cent. Another portion of 68.87 grains, incinerated in a similar manner, gave 4.065 per cent. of ashes: the mean of these is 3.942.

Of the same powder, 124.17 grains exposed in a closely covered platinum crucible to a clear red heat till all flame had subsided, left of intumescent coke 78.75 grains. Hence the loss was 36.589 per cent.

The composition deduced from this analysis may be stated as follows:

Moisture - - - - - - - -	2.597
Other volatile matter - - - - - - -	33.992
Earthy matter - - - - - - - -	3.942
Fixed carbon - - - - - - - -	59.469
	100.

Volatile to fixed combustible=1 : 1.7495.

During the experiments on evaporation, 2,465.5 pounds were consumed, leaving of—

Ashes - - - - - - - -	87.000	pounds.
Clinker - - - - - - - -	41.000	"
Soot - - - - - - - -	14.365	"

Of matter absolutely incombustible, there were in the—

Ashes - - - - - - - -	82.143	pounds.
Clinker - - - - - - - -	41.000	"
Soot - - - - - - - -	3.341	"
Total - - - - - - -	126.484	"
From which deduct wood ashes - - - -	0.997	"
And it leaves - - - - - - -	125.487	pounds,

=4.9739 per cent. of the coal burned.

The clinker is in this case a mixture, in apparently equal quantities, of black vitreous porous portions, with light colored unvitrifiable shaly materials.

The whole is sufficiently friable to be easily broken, and shows no tendency to form continuous tenacious sheets. It was observed, however, in one instance, on clearing out the furnace, to adhere with considerable

force to the grate bars. It weighs 28.28 pounds per cubic foot; the ashes weigh 55.79, and the soot 3.29 pounds per cubic foot; the latter material being the lightest produced by any sample in the whole series. From the oxide of lead, specimen *a* of this coal reduced 24.91 times its weight, which, for one of combustible matter of the specimen, is 26.527.

I cannot offer an analysis by the organic method of any specimen from the Cannelton sample, but am enabled, through the kindness of the distinguished proprietor of an estate in the same coal field at Caseyville, Kentucky, to present the following result, which, so far as the *constitution of the combustible matter* is concerned, may be considered as affording a type of the Cannelton coal.

The specimen referred to had a specific gravity of 1.392.

By exposure to a temperature of 250° Fah., it lost 1.151 per cent. of its weight.

By rapid coking, the total loss is 37.96, and by slow coking 31.82 per cent.

Four incinerations (the results of which very nearly approached each other) gave the mean amount of earthy matter 23.6875 per cent. Hence the proximate ingredients were as follows:

Moisture - - - - - - -	1.151
Other volatile matter, (by slow coking) - -	30.669
Earthy matter - - - - - - -	23.687
Fixed carbon - - - - - - -	44.493
	100.
Volatile to fixed combustible - -	1 : 1.46

Of this coal, well dried, 4.21 grains (equal to 4.259 grains of the raw coal) were taken for analysis. This was treated in a combustion-tube with fused chromate of lead—a small portion of chlorate of potash being used to complete the combustion, and for that purpose placed near the bottom of the tube.

Having conducted the process with all the usual precautions, the analysis yielded 8.96 grains carbonic acid, and 1.92 grain water.

This gives *carbon* - - - - -	2.4436 grains.
hydrogen - - - - -	0.2133 "
	2.6569 "
The ashes in 4.250 grains of the raw coal was -	1.0088 grain.
And the water - - - - - -	0.0490 "

The total combustible matter was therefore 3.2012 grains; from which deducting 2.6569, the remainder (oxygen and azote) is 0.5443 grain.

The raw coal will, therefore, be composed of the following ingredients, viz:

Moisture - - -			= 1.151	
Carbon -	2.4436	÷ 4.259	= 57.375	Combustible ingredients.
Hydrogen -	.2133		= 5.008	
Oxygen and azote	.5443		= 12.779	
Ashes - - -			= 23.687	
			100.	

As the fixed carbon by slow coking was 44.493, it appears that the portion of carbon volatilized was - 57.375—44.493=12.882 per cent.

hydrogen - - - - - -	5.008
oxygen and azote - - - - -	12.779
	30.669

Comparing together the combustible ingredients alone, there will be found in 100 parts of—

Carbon - - - - -	76.335=12.722	atoms.
Hydrogen - - - - -	6.663= 6.663	"
Oxygen and azote - - -	17.002= 2.125	"

In order to verify the above, I analyzed another portion of the same powder, by means of the scale oxide of copper; using, however, more than double the quantity of coal previously employed.

8.87 grains of the dried coal (equal to 8.9733 grains of raw coal) were treated with that oxide recently recalcined and heated, and then placed with all care in a dry tube, and all moisture carefully exhausted.

The carbonic acid collected was - -	18.66	grains.
Water - - - - - - -	3.86	"
Hence the—		
Carbon is - - - - - -	5.0891	grains.
Hydrogen - - - - - -	0.4266	"

The moisture and ashes being deducted from the raw coal, leave 8.9733—2.2288=6.7445 of combustible matter; from which taking the carbon and hydrogen, there remains 1.2288 grain for oxygen and azote. From these data the following results are derived:

Moisture, as above - -		= 1.151	
Carbon - -	5.0891÷8.9733	=56.714	Combustible materials.
Hydrogen -	.4266÷8.9733	= 4.754	
Oxygen and azote - -		=13.694	
Ashes - - - -		=23.687	
		100.	

Deducting, as before, moisture and ashes, the combustible ingredients are related to each other as follows:

Carbon - - - - -	75.456=12.576	atoms.
Hydrogen - - - - -	6.325= 6.325	"
Oxygen and azote - - -	18.219= 2.252	"

I am disposed to attribute the slight superiority of hydrogen in the first over that in the second analysis to a trifling amount of moisture adhering to the chlorate of potash; for though this substance is generally regarded as anhydrous, I found, by exposure in a porcelain crucible to a temperature of 390°, at which it began to fuse, the loss was 0.82 per cent., as already stated in a former part of this report. Having, in a second experiment, with chromate of lead and chlorate of potash treated 12.32 grains of dried coal, I procured 5.29 grains of water, which makes the hydrogen 6.274 per cent. of the combustible matter; and in a fourth trial, in which the *precipitated* oxide of copper was employed, and the weight of dried coal was 6.38 grains, the proportion of hydrogen obtained was 6.596. Hence the following affords the result of these four trials:

				Hydrogen.
1. With chromate of lead and *undried* chlorate of potash - -	4.21 grains of dried coal gave			6.663 p. c.
2. With scale oxide of copper - -	8.87	"	"	6.325 "
3. With chromate and dried chlorate - -	12.32	"	"	6.274 "
4. With precipitated oxide of copper - -	6.38	"	"	6.596 "
Mean - - - - -				6.4645 "

I may mention that Richardson found the "parrot" coal of Edinburgh to possess 6.326 per cent. of hydrogen among its combustible ingredients, which agrees *very nearly* (that is, within the thousandth part of one per cent.) with my determination of the proportion in Caseyville coal, by means of the scale oxide of copper.

Assuming the mean of the above two determinations of the carbon, and that of the four trials for hydrogen, to represent truly the relation of those two constituents in the combustible matter of this coal, we have the means of computing the heating power of those elements, according to the principle hitherto adopted by chemists.

The combustible will consist of—

Carbon - - - - - - -	75.8950
Hydrogen - - - - - - -	6.4645
Oxygen and azote - - - - - -	17.6405
	100.

Deducting one-eighth of the weight of oxygen from that of the hydrogen, there remains 4.259.

Hence $0.04259 \times 62535 = 2663 =$ the heating power of the hydrogen; and $0.75895 \times 12906 = 9795 =$ the heating power of the carbon.

Reduced to steam-generating power, these numbers give—

	2.585	lbs. of steam to 1 lb. of combustible, due to hydrogen,
and	9.509	" " " " carbon.
Total	12.094	

By reference to the table of experiments on gases drawn from the flues, it will be seen that two trials were made on the products of combustion from Cannelton coal, and that the mean heating power of one pound of coal (as the same was applied to all the four absorbents of that power) was 8.977 pounds of water generated from 212°. As the moisture and waste amounted to 6.018 per cent., the combustible is 0.93928 of the coal. Hence $8.977 \div 0.93928 = 9.557 =$ the heating power of one of combustible, which, as in a preceding case, is almost identical with the above calculated steam-generating power of the carbon alone, independent of the hydrogen.

Trial was made of this coal in the chain and anchor shops. In the former, 60 pounds were found sufficient to put in only 5 links of a chain $1\frac{5}{16}$ inch in diameter. It produced a great blaze at first, but seemed soon to "go away into chaff," as expressed in the significant language of the workman employed in testing it. The coal of Atkinson & Templeman had put in of the same chain 8 links by 60 pounds; and the mean evaporative power

of that sample was 10.699 of water from 212°, while that of the Cannelton coal was 7.341. Now 10.699 : 7.341 :: 8 : 5.4. This last is the number of links which the Cannelton coal ought to have made, had its heating power in the smith's forge been proportionate to its evaporative power. The two results agree within the fraction of four-nineteenths of a link. The true numbers of links would probably have been 80 and 54, had ten times as much coal been employed in each case.

In the anchor shop it proved very light, made a transient hot blaze, almost insupportable by the workmen; but as soon as that was gone, left scarcely anything behind, and made no hollow fire.

In an office grate, a lump 15 inches in diameter was laid on a mass of ignited coke. It immediately took fire, and in three minutes was giving off a brilliant flame. From its flaky texture, it speedily disintegrated into flat masses, burning with little intumescence, and scarcely any tendency to agglutination. This property allows a free passage to the air, favors rapid combustion, and causes the exhibition of an exceedingly brilliant light. When the white flame had subsided, it was followed by one of a bright blue or purplish tint, (cyanogen?) which having subsided, left a light porous glowing coke, falling readily into small fragments, which preserve, to some extent, the original lamellated appearance of the coal. On the grate, under the steam boiler, it was observed to ignite readily; and it took only half an hour to bring the boiler into steady action, from the time the wood was withdrawn, and the charging with coal had commenced. No serious inconvenience was felt from the passage of fragments through the grate. Its prompt and rapid action appears to adapt it, in a remarkable manner, to the purposes of Western steamboats. It seems to bear transportation better than any other sample of bituminous coal which came under notice. A large box which had come from the mines by steamboat, wagon, railroad car, and drays, and had been subjected to five or six transhipments, contained scarcely any fine coal. Its very slight tendency to soil will also recommend it. The average quantity of unburnt coke left on the grate was but $6\frac{3}{8}$ pounds. This coal was received in three distinct packages, at as many different times; and there is reason to think that one part was taken from nearer the outcrop of the bed than the rest. This supposition is strengthened not only by the appearance of the coal, but by the difference in evaporative effects on the two trials, and the difference in amount of waste; the latter being one-fourth greater on the first trial than on the second. The average weight per cubic foot was more than 3.5 pounds (or upwards of 7 per cent.) less on the second than on the first trial.

The coal now under consideration was the only really available sample forwarded for trial from the great coal fields of the West. I may add, however, that two or three specimens were offered for *analysis*, besides that received from Caseyville, already noticed.

A specimen from Wheeling, Virginia, had the following composition—its specific gravity being 1.2804:

The hygrometric moisture was	1.414	per cent.
Other volatile matter	42.626	"
Fixed carbon	52.030	"
Earthy matter	3.930	"
	100.	

The sulphur was 0.703 of one per cent.; the fixed to volatile combustible 1 : 1.22. The surfaces of deposition are covered with mineralized charcoal. The main partings are beautifully defined planes, inclined 88° to those of deposition. The cross partings are also pretty well defined, and exhibit a pitchy lustre. It is a rich coking coal, and will produce a large portion of highly illuminating gas.

A specimen from the Osage river, Missouri, had, in its dry state, a specific gravity less than 1, as it floated on water. When allowed to imbibe water, it sank, and was, when fully saturated, found to have a specific gravity of 1.2. It contained of—

Moisture, expelled at 230° - - - -	1.67	per cent.
Other volatile matter - - - -	41.83	"
Fixed carbon - - - - -	51.16	"
Earthy matter - - - - -	5.34	"
	100.	

A trial for sulphur gave 0.482 per cent of that material.

From the above analysis, the volatile is to the fixed combustible as 1 : 1.223. An analysis by the chromate of lead and the chlorate of potash, proved the combustible matter of this specimen to consist of—

Carbon - - - - -	81.855=13.642	atoms.
Hydrogen - - - -	6.168= 6.168	"
Oxygen, &c. - - - -	11.977= 1.497	"
	100.	

From this analysis, the computation of evaporative power, assumed to be proportionate to the carbon, will give a result of 10.256 to 1 of combustible, and of 9.66 to 1 of the raw coal.

A specimen of pure bitumen, having a specific gravity of 1.1558, was found to contain of—

Volatile matter - - - - - - -	72.439
Fixed carbon - - - - - - -	24.799
Earthy matter - - - - - - -	2.762
	100.

In this substance, therefore, the volatile is to the fixed combustible as 1 : 0.3423. Analyzed with the scale oxide of copper, 8.16 grains of this bitumen yielded 5.73 grains of water, and 22.6 grains of carbonic acid; from which is deduced the following composition of 100 parts of its combustible matter, viz:

Carbon - - - - - - - -	77.679
Hydrogen - - - - - - -	8.023
Oxygen and azote - - - - -	14.298
	100.

The calculated evaporative power of the carbon in 1 of this combustible matter, is 9.464.

TABLE CLXXXIII.—CAN

First trial—upper damper 8 inches open; air plates closed;

Date.	Hour.	Temperatures of the: Open air entering below ash pit.	Wet bulb thermometer.	Air entering back of grate.	Gas entering chimney.	Water in tank.	Steam in boiler.	Attached thermometer.	Height of barometer.	Height of manometer.	Volumes of air in manometer.	Height of water in syphon.	Weight of water supplied to boiler.	Weight of charges of coal.
	h. m. A. M.													
Nov. 7	8 15	43	41	148	-	46	202	42	30.01	0.373	6.83	0.18	-	-
	9.45	46	41	128	246	47	231	42	30.01	0.578	4.80	0.39	-	99.50
	10.15	44	42	132	272	46	234	42	30.01	0.575	4.83	0.34	304	106.25
	10.45	44	42	146	261	46	234	43	30.01	0.576	4.82	0.31	907	98.75
	11.10	44	42	168	294	47	232	44	30.01	0.572	8.86	0.35	1284	91.00
	11.45	43	41	208	297	44	234	44	30.01	0.576	4.82	0.38	1939	97.75
	P. M. 0.15	44	42	232	305	44	235	44	30.00	0.568	4.90	0.37	2426	99.75
	0.45	47	43	254	306	44	233	43	29.99	0.577	4.81	0.35	2791	96.25
	1.15	48	45	270	307	44	233	43.5	29.99	0.574	4.84	0.35	3211	104.50
	1.45	48	45	282	314	44	233	44	29.97	0.573	4.85	0.34	3726	-
	2.15	48	46	292	320	44	233	44	29.97	0.573	4.85	0.37	4064	93.50
	2.45	49	47	298	312	45	233	45	29.98	0.574	4.84	0.36	4831	94.50
	3.05	49	47	303	320	45	233	45	29.99	0.573	4.85	0.34	4831	-
	3.30	51	48	310	321	44	232	45	29.99	0.564	4.94	0.34	5153	97.00
	4.00	51	48	314	316	44	232	45	30.00	0.574	4.84	0.37	5653	-
	4.30	51	48	320	330	44	233	46	30.00	0.572	4.86	0.35	6121	96.75
	5.00	52	48	325	335	45	233	46	30.00	0.576	4.82	0.36	6611	110.50
	5.25	51	47	337	332	44	230	46	30.02	0.578	4.80	0.33	7311	-
	10.00	45	40.5	278	204	44	230	43	30.03	0.544	5.13	0.28	7311	-
	10.12	44	40	284	196	44	229	43	30.03	0.524	5.32	0.28	7473	-
Nov. 8	A. M. 6.10	41.5	37.5	209	174	44	216	40.5	30.07	0.416	6.40	0.25	7476	-
	6.40	41	38	206	172	44	214	40.5	30.07	0.405	6.51	0.24	7516	-

Period of steady action, from 10*h.* 45*m.* a. m. to 4*h.* 41*m.* p. m.—5*h.* 56*m.*; coal supplied during that time, 981.5 lbs.; water supplied to boiler during that time, 5,393 lbs: water to 1 of coal, 5.495.

NELTON (INDIANA) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	36.8	105	-	-	Morning cloudy; wind W., light; commenced firing at 8*h.* 20*m.* a. m.
9.45	30.1	82	+15	-	Wood consumed, 176¼ lbs.; commenced charging with coal.
10.15	38.1	88	38	1.610	Steam blows off at 10*h.* a. m.; damper set at 8 inches;
10.45	38.1	102	27	3.195	steam allowed to escape from back valve at 10*h.* 32*m.* a. m.; snowing and raining. This coal ignites promptly;
11.02	38.1	124	62	2.397	at 11*h.* a. m. snowing.
11.37	36.8	165	63	2.975	Filled tank at 11*h.* 15*m.* a. m.; grate bars red.
11.57	38.1	188	70	2.580	Commenced drawing gases at 0*h.* 1*m.* p. m.; drew in 46 minutes 100 cubic inches, which gave 0.99 grain water,
0.20	35.5	207	73	1.933	carbonic acid 7.40 grains, oxygen 5 cubic inches.
0.59	40.0	222	74	2.225	Ceased snowing.
-	40.0	234	81	2.748	
2.04	40.0	244	87	1.790	
2.40	44.1	249	79	-	Filling tank; water 1 inch above normal level.
-	44.1	254	87	2.437	Water at normal level; tank filled.
3.23	43.8	259	89	2.045	
-	43.8	263	84	2.649	Wind W.; clearing off.
4.03	43.8	269	97	2.477	
4.41	42.4	273	102	2.596	
-	41.1	286	102	-	Contents of ash pit thrown on grate; damper reduced to 3 inches.
-	30.4	233	—26	-	Water 0.45 inch below normal level; closed damper and air port.
-	30.9	240	—33	-	Water 0.07 inch below normal level, after letting in 162 pounds.
-	26.7	167.5	—42	-	Water 0.38 inch below normal level.
-	30.3	165	—42	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker	26.25
Ashes	45.25
Ashes behind bridge	3.50
	75.00
Deduct wood ashes	0.54
Total waste from coal	74.46
Soot	9.625
Coke	7.00

TABLE CLXXXIV.—CAN

Second trial—upper damper 8 inches open; air plates open;

coal.
-
7.75
2.00
5.00
......
-
1.50
6.50
3.25
7.75
8.75
1.25
8.25
-
6.00
7.25
8.50
-
-
-
-
-

Period of steady action, from 0*h*. 54*m*. p. m. to 7*h*. 5*m*. p. m. = 6*h*. 11*m*. Coal supplied to the grate, 907 lbs.; water supplied to the boiler, 6,009.38 lbs.; water to 1 of coal, 6.625.

NELTON (INDIANA) COAL.

steam thrown into chimney, and small furnace in action.

Time each charge was on grate.	Dew point, by calculation.	Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 63 feet.
h. m.					
-	34.0	126	-	-	Commenced firing; sky overclouded; wind NW., brisk.
0.00	27.9	103	+ 4	-	Wood consumed, 151 lbs.; commenced charging with coal.
0.23	27.9	105	13	2.135	Steam allowed to blow off at 0*h*. 8*m*.; damper set at 3 inches; air plates opened at 0*h*. 13*m*. Commenced drawing gases at 1*h*. 19*m*.; drew in 45 minutes 100 cubic inches, which gave water 1.42 grain, carbonic acid 7.38 grains, oxygen 7.708 cubic inches.
0.54	27.5	115	31	2.331	
-.	29.5	136	69	2.119	
1.42	26.4	157.6	89	3.126	
2.20	31.4	167	74	2.723	
2.22	34.8	180	85	2.628	
3.20	35.0	182	79	2.575	
3.47	33.2	212	100	2.688	Filling tank; water 1.2 inch below normal level.
4.30	38.2	221	88	-	Tank filled at 4*h*. 50*m*.
4.54	36.6	243	83	2.437	
-	38.2	251	108	3.078	
5.52	36.6	258	103	2.718	
6.23	36.6	262	105	2.527	Tank partly filled.
7.05	38.2	277	97	2.061	Contents of ash pit thrown on grate, and air plates closed at 7*h*. 30*m*.
-	38.5	281	79	-	28 lbs. of this coal in drying apparatus weighed (November 9) 27¾ lbs.
-	23.3	283	35	-	Water 0.65 inch below normal level.
-	27.9	281	28	-	Water left at 0.15 inch above normal level.
-	21.3	180	—34	-	Found water 0.55 inch below normal level.
-	21.3	176	—33	-	Water in boiler adjusted.

RESIDUA.

	Pounds.
Clinker - - - - - - - - - -	14.75
Ashes - - - - - - - - - -	36.75
Ashes behind bridge - - - - - - - -	1.50
Total clinker and ashes - - - - - - - -	53.00
Deduct wood ashes - - - - - - - - -	0.463
Total waste from coal - - - - - - - -	52.537
Coke - - - - - - - - - -	5.75
Soot - - - - - - - - - -	5.00

TABLE CLXXXV.—DEDUCTIONS FROM

Experiments on

	Nature of the data furnished by the respective tables.	1st Trial. Tab.CLXXXIII.	2d Trial. (Tab.CLXXXIV.)
		November 7.	*November* 8.
1	Total duration of the experiment, in hours	22.417	20.533
2	Duration of steady action, in hours	5.933	6.183
3	Area of grate, in square feet	14.07	14.07
4	Area of heated surface of boiler, in square feet	377.5	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75	18.75
6	Number of charges of coal supplied to grate	13.0	13.0
7	Total weight of coal supplied to grate, in pounds	1286.0	1191.75
8	Pounds of coal actually consumed	1279.0	1186.0
9	Pounds of coal withdrawn and separated after trial	7.0	5.75
10	Mean weight, in pounds, of one cubic foot of coal	49.461	45.836
11	Pounds of coal supplied per hour, during steady action	165.431	146.692
12	Pounds of coal per square foot of grate surface, per hour	11.758	10.426
13	Total waste, ashes and clinker, from 100 pounds of coal	5.8217	4.429
14	Pounds of clinker alone, from 100 pounds of coal	2.0397	1.2319
15	Ratio of clinker to the total waste, per cent.	35.036	27.811
16	Total pounds of water supplied to the boiler	7516.00	8019.0
17	Mean temperature of water, in degrees Fahrenheit	44°.40	42°.6
18	Pounds of water supplied at the end of experiment, to restore level	20.00	125.0
19	Deduction for temperature of water supplied at end of experiment, in pounds	3.0	19.0
20	Pounds of water evaporated per hour, during steady action	909.096	971.9105
21	Cubic feet of water per hour, during steady action	14.545	15.551
22	Pounds of water per square foot of heated surface per hour, by one calculation	2.408	2.575
23	Pounds of water per square foot, by a mean of several observations	2.404	2.631
24	Water evaporated by 1 of coal, from intial temp. (a) final result	5.872	6.745
25	Water evaporated by 1 of coal, from initial temp. (b) during steady action	5.495	6.625
26	Pounds of fuel evaporating one cubic foot of water	10.6437	9.2661
27	Mean temperature of air entering below ash pit, during steady pressure	47°.64	50°.7
28	Mean temp. of wet bulb thermom., during steady pressure	44°.76	44°.4
29	Mean temperature of air, on arriving at the grate	254°.06	241°.93
30	Mean temperature of gases, when arriving at the chimney	305°.18	309°.13
31	Mean temperature of steam in the boiler	232°.82	233°.93
32	Mean temperature of attached thermometer	44°.20	46°.63
33	Mean height of barometer, in inches	29.997	30.1233
34	Mean number of volumes of air in manometer	4.843	4.8113
35	Mean height of mercury in manometer, in atmospheres	0.5737	0.5769
36	Mean height of water in syphon draught gauge, in inches	0.3561	0.4183
37	Mean temperature of dew point, by calculation	39°.88	33°.2
38	Mean gain of temperature by the air, before reaching grate	206°.42	191°.23
39	Mean difference between steam and escaping gases	79°.85	84°.5
40	Water to 1 of coal, corrected for temperature of water in cistern	5.872	6.745
41	Water to 1 of coal, from 212°, corrected for temperature of water in cistern	6.8275	7.8543
42	Pounds of water, from 212°, to 1 cubic foot of coal	337.70	360.01
43	Water, from 212°, to 1 pound of combustible matter of the fuel	7.2495	8.2183
44	Mean pressure, in atmospheres, above a vacuum	1.4604	1.4734
45	Mean pressure, in pounds per square inch, above atmosphere	6.7987	6.9920
46	Condition of the air plates at the furnace bridge	Closed.	Open.
47	Inches opening of damper, (U. upper)	U. 8	U. 8

TABLES CLXXXIII, CLXXXIV.

Cannelton (Ia.) coal.

Averages.	Remarks.
6.875	
47.6485	
156.0615	
11.092	
5.1254	
1.6358	
31.4235	
940 5033	
15.048	
2.4915	
6.3085	A tolerable accordance will be found between the final results in the two trials, as seen in this line, with those of the next below, derived from observations during the period of steady action.
6.060	
9.9549	
247°.99	
207°.155	
0.3872	
198°.825	
82°.175	
6.3085	
7.3409	
348.855	
7.7339	An obvious advantage was obtained in economy, both of time and fuel, in using the open air plate, as in the second trial.
1.4669	
6.8953	

Having completed the description of the fourth class of coals, I may here exhibit its relations to the series from Virginia. The synoptical table (page 551) will show that the average weight per cubic foot of eight samples of foreign and western coals is 49.31 pounds. The table already given of eleven samples of Virginia coals proves that they weighed 49.28 pounds. Eight foreign and western coals gave an average evaporative power of 7.984. Ten Virginia coals gave 8.477. Eight foreign and western, all burned with the chimney 63 feet high, evaporated on an average 13.778 cubic feet of water per hour. Six Virginia coals, burned with the same height of chimney, gave 13.73 cubic feet per hour. The lead reducing power of the *combustible matter* of the fourth class, compared with their evaporative power and with the ratios of fixed to volatile material, is seen in the following:

Name of coal.	Steam to 1 of combustible.	Lead to 1 of combustible.	Fixed to 1 volatile matter.
Pictou, (New York)	9.710	28.18	2.105
Pictou, (Cunard's)	9.648	26.69	2.593
Newcastle	9.178	27.55	1.601
Pittsburg	8.942	28.89	2.014
Sidney	8 497	29.15	2.838
Liverpool	8.255	27.88	1.513
Cannelton	7.734	26.53	1.719
Scotch	7.719	27.03	1.257
Average	8.710	27.74	1.955
Average of ten Virginia coals	9.523	28.194	2.054

No. 9.

Experiment on dry pine wood.

During the progress of these experiments, there were used in heating up the boiler and its contents, with the brick work of the furnace, 25,367 pounds or 9 43 cords of dry yellow pine wood. This was of the ordinary kind, procured for use under the boilers which drive the engines in the navy yard.

It was brought to the apparatus from a pile kept in the open air, and consequently was dependent, in some degree, on the state of the weather for the quantity of moisture which adhered to it, and which caused a degree of diversity in the heating power it exhibited at different times.

It will be found, on computing the weight of wood required to raise the temperature of the boiler 1°, that this weight was generally the less, as the total range of temperature through which the boiler was heated was greater. It must evidently be so, because, in commencing many of the experiments, the temperature was either at or above 212°, and almost the whole heating power of the fuel was then expended in generating steam, or increasing the density of that already existing in the boiler. When, on the contrary, the experiment commenced with the temperature of the water within the boiler 100° or more below the boiling point, a considerable proportion of the heat was expended in merely raising temperature. This subject will be made intelligible by the following short table, which has been drawn from the various tables of daily observations on the amount of wood burned, as seen under the head of

"remarks," and from the corresponding ranges of temperature through which the water in the boiler was raised.

TABLE CLXXXVI.

Of the efficiency of pine wood in raising temperature.

Number of degrees through which the temperature was raised.	Number of pounds of wood required to each degree.	Number of degrees through which the temperature was raised.	Number of pounds of wood required to each degree.	Number of degrees through which the temperature was raised.	Number of pounds of wood required to each degree.
4°	16.43 lbs.	28°	6.15 lbs.	64°	4.46 lbs.
6	12.32	30	6.27	76	3 89
8	10.23	34	6.66	92	4 21
10	8.15	36	6.47	100	4.62
12	7.01	40	4 65	102	4 32
14	7.35	42	4.40	106	4.19
16	6.81	44	4 54	118	3.87
18	6.48	46	4.56	126	4 05
20	6.12	48	4.27	132	3.51
22	6.20	54	4.56	149	3.79
24	6.50	58	4.09	157	3.71
26	6.27	62	4.57	171	3.86

The deviations from a regularly diminishing series of numbers, expressing the weights of wood for 1°, are doubtless caused in part by the fact that the wood was sometimes burned with the *lower* damper open, sometimes with the *upper;* and that occasionally the ash pit doors were open while burning wood, though closed as soon as the charging with coal commenced.

The heating with wood generally terminated at about 230°, or 18° above the boiling point.

The wood on which the following experiment was made was formed into a pile 8 feet long and 4 feet high. It was stated by the engineer of the navy yard to be, both in quality and length of billets, a fair average of that generally in use at the yard.

In order to ascertain as nearly as possible the true cubical contents of the pile, every billet was measured by fixing a scale of inches in an upright position, and placing each billet against it with its lower extremity resting on the floor, and the shoulder of its upper axe-kerf brought against the scale. The portion which thus projected above the shoulder at one end was considered a just equivalent of what was taken away from the full size of the piece at the lower extremity.

In this manner the average length of the 201 pieces of which the pile was composed, was found to be 42.134 inches, and the pile to contain 112 35 cubic feet. It weighed 2,360.5 pounds. Had it been composed of pieces 4 feet long, and constituted a true "cord of wood," its weight would have been 2,689.2 pounds.

The charges were made to exceed as little as possible 100 pounds each. The temperature was, as usual, raised by burning a weighed quantity of wood; and, when it had reached its usual point, the unburnt portion was withdrawn, and a charge from the pile was substituted.

TABLE CLXXXVII.—

Upper damper 10 inches open; air plates closed;

Period of steady action, from 8*h*. 45*m*. a. m. to 6*h*. 20*m*. p. m.=9*h*. 35*m*. Wood supplied to the grate during that time, 2,155.26 lbs.; water to boiler, 8,303 lbs.; water to 1 of wood, 3.8524.

DRY PINE WOOD.

steam thrown into chimney, and small furnace in action.

		Gain of temperature by the air before reaching grate.	Difference of temperature between steam and escaping gases.	Water per square foot of absorbing surface per hour.	REMARKS.—Grate surface 14.07 square feet; length of circuit of heated gases 121 feet; height of chimney 60 feet.
—	56.3	52		-	Commenced firing at 6h. 19m. a. m.; water 0.93 inch below normal level.
—	51.6	51.6	+29	—	Water at 212°, stood 0.9 inch below normal level.
8.00	55.8	57.5	1	—	20 lbs. of water added to the boiler, which brought it to 0.5 inch above normal level; commenced charging with wood from pile at 8h. 20m. a. m.; wood consumed to raise steam, 282½ lbs.
8.46	54.4	63	23	2.066	
9.16	[illegible]	71	38	1.722	
9.37	52.0	92	65	2.649	Steam allowed to escape from front valve at 8h. 26m. a. m.; damper set at 10 inches at 8h. 40m. a. m.; steam allowed to escape from back valve at 8h. 46m. a. m.; clear; wind W., brisk.
10.00	54.5	107	57	2.869	
10.24	[illegible]	128	63	1.727	
10.58	[illegible]	135	68	2.543	Commenced drawing gases at 10h. 31m. a. m.; drew in 49.5 minutes 100 cubic inches, which gave water 1.02 grain, carbonic acid 4.80 grains, oxygen 12.6 cubic inches; during the drawing, fired up once without stopping the drawing; filled tank at 11h. 46m. a. m.; double weighted back valve at 0h. 15m. p. m.
11.20	51.0	150	[illegible]	-	
11.46	49.5	[illegible]	79	[illegible]	
0.26	44.1	172	76	1.765	
0.52	45.7	175	74	1.944	
1.16	43.8	[illegible]	89	[illegible]	Placed 11 lbs. 15 oz. of this wood (cut into small pieces) in drying apparatus; commenced drawing gases at 1h. 16m. p. m.; drew in 45 minutes 100 cubic inches, which gave water 2.22 grains, carbonic acid 4.72 grains, oxygen 10 cubic inches.
1.47	45.7	195	86	2.660	
[illegible]	42.5	200	[illegible]	1.923	
3.00	45.0	213	94	2.907	
3.28	45.0	[illegible]	97	1.808	Steam allowed to escape from back valve at 2h. 48m. p. m.
3.50	45.0	229	105	2.124	
4.22	—	—	-	—	Filled tank.
4.43	44.1	240	105	[illegible]	
5.12	44.1	260	[illegible]	2.167	
5.43	45.8	267	104	2.994	
—	45.0	272	[illegible]	1.260	Wood in drying apparatus weighs 11 lbs. 6 oz., which is now added to the rest, and burned.
6.20	43.2	283	[illegible]	3.020	
—	[illegible]	271	89	—	Damper reduced to 4 inches.
—	[illegible]	236	6		
—	37.7	244	—1	—	Water in boiler adjusted; valve double weighted.
—	[illegible]	157	—27	-	Water in boiler still accords with its present temperature.

RESIDUA.

	Pounds.
Ashes - - - - - - - - - - -	7.126
Ashes behind bridge - - - - - - - - - -	1.000
	[illegible]
Deduct ashes of wood to raise steam - - - - - -	[illegible]
Total ashes - - - - - - - - - - -	7.250
Soot - - - - - - - - - - - -	1.75

TABLE CLXXXVIII.—DEDUCTIONS FROM TABLE CLXXXVII.

Experiments on dry pine wood.

	Nature of the data furnished by the preceding table.	*Table* CLXXXVII.
		November 18.
1	Total duration of the experiment, in hours	25.617
2	Duration of steady action, in hours	9.583
3	Area of grate, in square feet	14.07
4	Area of heated surface of boiler, in square feet	377.5
5	Area of boiler exposed to direct radiation, in square feet	18.75
6	Number of charges of wood supplied to grate	22.0
7	Total weight of wood supplied to grate, in pounds	2360.5
8	Pounds of wood actually consumed	2360.5
9	Pounds of wood withdrawn and separated after trial	*0.0
10	Mean weight, in pounds, of one cubic foot of wood	21.009
11	Pounds of wood supplied per hour, during steady action	223.86
12	Pounds of wood per square foot of grate surface, per hour	15.87
13	Total waste from 100 pounds of wood	0.3074
14	Total pounds of water supplied to the boiler	9581.0
15	Mean temperature of water, in degrees Fahrenheit	53°.2
16	Pounds of water supplied at the end of experiment, to restore level	†0.0
17	Deduction for temperature of water supplied at end of experiment, in pounds	†0.0
18	Pounds of water evaporated per hour, during steady action	866.43
19	Cubic feet of water per hour, during steady action	13.86
20	Pounds of water per square foot of heated surface per hour, by one calculation	2.2951
21	Pounds of water per square foot, by a mean of several observations	2.2923
22	Water evaporated by one of wood, from initial temperature (a) final result	4.0588
23	Water evaporated by one of wood, from initial temp. (b) during steady action	3.8524
24	Pounds of fuel evaporating one cubic foot of water	15.3987
25	Mean temperature of air entering below ash pit, during steady pressure	67°.76
26	Mean temperature of wet bulb thermometer, during steady pressure	56°.62
27	Mean temperature of air, on arriving at the grate	249°.71
28	Mean temperature of gases, when arriving at the chimney	315°.19
29	Mean temperature of steam in the boiler	233°.84
30	Mean temperature of attached thermometer	63°.9
31	Mean height of barometer, in inches	30.032
32	Mean number of volumes of air in manometer	4.972
33	Mean height of mercury in manometer	0.5607
34	Mean height of water in syphon draught gauge, in inches	0.2375
35	Mean temperature of dew point, by calculation	47°.37
36	Mean gain of temperature by the air, before reaching grate	181°.95
37	Mean difference between steam and escaping gases	83°.75
38	Water to one of wood, corrected for temperature of water in cistern	4.0588
39	Water to one of wood, from 212°, corrected for temperature of water in cistern	4.6922
40	Pounds of water, from 212°, to one cubic foot of wood	98.578
41	Water, from 212°, to one pound of combustible matter of the fuel	4.7066
42	Mean pressure, in atmospheres, above a vacuum	1.4577
43	Mean pressure, in pounds per square inch, above atmosphere	6.7592
44	Condition of the air plates at the furnace bridge	Closed.
45	Inches opening of damper	Upper 10

* The charcoal left on the grate did not amount to one quarter of a pound.

† The experiment was concluded before leaving the apparatus for the night; hence no deduction is here necessary.

TABLE CLXXXIX.—*Synoptical view of the characters, composition, and efficiency, of foreign and western coals.*

Designation of coals.	Density.						Composition, in 100 parts.							
	Specific gravity.	Pounds per cubic foot, calculated from specific gravity.	Number of experiments, to determine actual weight.	Weight, in pounds per cubic foot, by experiment.	Ratio of actual to calculated weight.	Cubic feet of space required to stow one ton.	Moisture, determined by steam drying apparatus.	Volatile matter, other than moisture.	Sulphur.	Fixed carbon.	Coke.	Earthy matter.	Ratio of fixed to volatile combustible matter.
Foreign coals.													
Pictou, (from New York) - -	1.318	82.35	39	53.548	0.6502	41.83	2.567	27.063	0.769	56.981	70.370	13.389	2.103
Sidney - - - -	1.338	83.66	17	47.441	0.5670	47.22	3.125	23.810	-	67.570	73.065	5.495	2.838
Pictou, (Cunard's) - - -	1.325	82.83	20	49.250	0.5945	45.48	0.781	25.975	-	60.735	73.243	12.508	2.593
Liverpool - - - -	1.262	78.89	40	47.878	0.6069	46.78	0.892	39.587	0.376	54.899	59.521	4.622	1.513
Newcastle - - - -	1.257	78.54	40	50.822	0.6470	44.08	2.007	35.597	0.230	56.996	62.396	5.400	1.601
Scotch - - - -	1.519	94.95	38	51.092	0.5380	43.84	3.013	38.837	0.358	48.812	58.150	9.338	1.257
Coals from west of the Allegheny mountains.													
Pittsburg - - - -	1.252	78.37	2	46.912	0.5980	47.85	1.397	36.603	0.160	54.926	62.000	7.974	2.014
Cannelton, (Indiana) - -	1.273	79.54	26	47.649	0.5986	47.01	2.597	33.992	-	58.437	63.411	4.974	1.719
Dry pine wood - -	-	-	22	21.009	-	106.62	3.665	-	-	-	-	0.307	

TABLE CXC.—*Proportion of the several waste materials from the position and density*

Names of coals.	No. of days' burnings.	Pounds of coal burned.	ASHES.			CLINKER.		
			To coal burned, per cent.	Weight of, in lbs., per cubic foot.	Combustible of, per cent.	To coal burned, per cent.	Weight of, in lbs., per cubic foot.	Combustible of, per cent.
Beaver Meadow, slope No. 3	4	3944.50	10.9460	52.89	44.330	1.0130	34.07	1.253
Beaver Meadow, slope No. 5	4	4250.50	6.1491	51.40	27.580	0.5959	35.00	1.723
Forest Improvement - -	4	3810.00	6.1590	44.03	40.680	0.8111	30.75	1.455
Peach Mountain - -	6	7371.875	3.9392	58.09	22.013	3.0297	45.12	0.000
Lehigh - - -	4	3838.25	6.1445	46.55	26.910	1.0790	35.35	8.890
Lackawanna - -	4	4112.51	7.6886	50.95	34.555	1.2411	36.88	0.000
Lyken's Valley - -	3	2471.00	7.8424	52.06	36.800	4.4026	32.75	1.590
Beaver Meadow, (navy yard)	2	1897.34	6.7041	-	-	1.3996	-	-
Mixture, 1-5 Midlothian and 4-5 Beaver Meadow -	2	2050.00	3.9719	-	-	4.9132	-	-
Mixture, 1-5 Cumberland and 4-5 Beaver Meadow -	2	2074.00	5.0895	-	-	3.0871	-	-
Natural coke - -	4	4209.00	13.1476	56.98	47.220	5.3134	38.25	9.620
Coke of Midlothian coal -	1	1037.00	6.0310	-	-	10.5140	-	-
Coke of Neff's coal - -	1	994.25	9.7853	-	-	3.5504	-	-
New York and Maryland Mining Company - -	2	2127.75	7.2826	37.79	13.270	5.4259	41.75	0.000
Neff's - - -	4	4318.38	6.4303	37.20	10.060	4.5257	32.12	0.896
Easby's 1st sample - -	1	1158.00	7.0586	32.08	12.870	1.3260	29.00	1.143
Atkinson & Templeman's -	2	2318.25	5.8371	33.92	11.850	2.1251	31.62	0.485
Easby & Smith's - -	5	4474.50	6.6409	33.57	8.418	3.0455	36.62	2.300
Cumberland, (navy yard) -	1	786.50	12.2380	-	-	2.2886	-	-
Dauphin and Susquehanna -	3	2557.00	12.8612	44.62	37.760	3.5018	32.25	1.691
Blossburg - - -	4	4295.00	7.8078	44.50	8.360	3.3961	30.87	0.436
Lycoming Creek - -	3	3073.25	13.6580	37.79	20.950	3.2620	34.37	9.930
Quin's Run - - -	2	1883 25	7.5733	37.09	7.577	1.3122	29.70	9.512
Karthaus - - -	4	3643.84	4.2351	47.94	12.600	3.6588	32.75	2.130
Cambria County - -	4	3488.50	6.2761	43.19	6.244	3.4764	33.62	0.000
Barr's Deep Run - -	5	5072.75	6.3255	44.86	12.100	4.7481	33.50	0.873
Crouch & Snead's - -	4	3834.75	8.9694	40.92	7.208	5.3711	29.87	0.950
Midlothian, (900 feet shaft) -	3	3417.50	4.2356	53.51	9.687	6.4664	43.37	0.000
Creek Company's coal -	4	3769.63	4.2255	56.00	9.840	4.4151	39.50	0.000
Clover Hill - - -	4	3775.10	6.7421	53.81	14.930	3.8588	44.62	0.000
Chesterfield Mining Company	4	3876.00	4.8800	47.29	18.744	4.1887	37.62	0.000
Midlothian, (average) -	5	4506.39	6.0061	53.80	10 090	8.8209	37.50	0.968
Tippecanoe - - -	5	4904.75	5.6894	57.44	8.480	4.0339	43.37	3.915
Midlothian, (new shaft) -	3	2918.50	6.0446	56.65	16.180	4.2137	30.12	0.000
Midlothian, (screened) -	5	4132.00	6.9462	53.40	13.172	3.3290	39.37	0.000
Midlothian, (navy yard, average.)	2	1463.50	15.6800	-	-	4.4242	-	-
Pictou, (New York) -	4	4153.87	7.2455	38.56	5.907	6.1257	43.12	0.000
Sidney, (Cunard) - -	2	1601.12	3.7647	52.42	13 624	2.2153	40.12	5.371
Pictou, (Cunard) - -	2	1962.50	5.8698	39.01	4 077	6.1927	38.00	0.000
Liverpool - - -	4	3786 00	3.1783	53.70	16.930	1.8642	40.12	0.000
Newcastle - - -	4	4023.00	2.5353	51.11	14.684	3.1442	38.25	0.000
Scotch - - -	4	3860.00	4.4670	47.94	13.923	5.6315	39.87	8 670
Pittsburg - - -	1	208 38	7.3124	37.18	21.123	0.9406	-	13.240
Cannelton, (Indiana) -	2	2465.50	3.4896	55.79	5.583	1.6358	28.28	0.000
Pine wood - - -	1	2360.50	3.0740	29.14	-	-	-	-

furnace, compared with the weight of fuel burned, showing also the com-
of each material.

SOOT.			COKE.		
Total weight of, collected.	Weight of, in lbs., per cubic foot.	Ashes of, per cent.	Pounds left after each trial, average.	Ashes of *wood* consumed to raise temperature, in pounds.	REMARKS.—In this table, as well as in the several synoptical tables belonging to the respective classes of coal, the per centage of ashes includes those from behind the bridge.
3.87	21.39	67.72	112.370	1.372	
7.00	26.97	67.62	61.250	1.707	The soot and dust of this anthracite, digested and treated for sulphuric acid, yielded 2.045 per cent. of that material.
3.00	17.94	52.63	40.188	1.806	
6.00	22.40	51.75	26.646	2.257	
6.00	19.51	53.11	36.125	1.700	
5.00	14.60	65.28	57.190	2.647	The soot and dust of this anthradite contained 11.8 per cent. of matter volatile at red heat, and 22.9 per cent. of fixed carbon.
1.75	21.56	37.60	18.000	0.952	
-	-	-	107.080	0.870	
-	-	-	60.875	1.587	
-	-	-	53.250	2.742	
11.50	22.67	46.66	43.687	2.786	The dust from flues contained 4.96 per cent. of its weight in sulphuric acid.
1.00	-	-	9.500	1.173	
1.50	-	-	16.000	1.786	
8.50	12.16	47.27	10.125	1.073	
14.62	12.64	83.16	6.156	1.966	
5.25	16.69	52.60	18.250	0.907	
11.50	15.77	55.21	5.125	1.642	
15.75	24.28	51.41	5.350	2.219	The soot contained 9.17 of volatile matter, and 39.42 per cent. of fixed carbon.
-	-	-	13.500		
5.75	12.45	51.32	23.670	1.103	
14.00	12.06	54.17	18.750	1.157	
11.50	16.29	54.44	46.250	1.118	The soot contains 11.87 of volatile matter, and 33.09 per cent. of fixed carbon.
6.75	10.06	48.65	14.750	1.234	Soot contains 16.03 of volatile matter, and 36.32 per cent. of fixed carbon.
-	15.64	-	52.531	2 502	
4.00	7.83	44.14	14.810	3.369	
21.50	12.23	45.29	6.400	2.361	
34.75	25.51	66.49	6.000	1.969	
14.12	5.74	43.37	5.917	0.999	
20.75	14.33	65.73	10 530	2.584	
42.00	9.20	56.33	11.512	3.369	
36.25	22.70	71.33	10.469	1.656	
28.00	19 06	63.34	6.442	2.370	
43.50	5.54	35.26	11.250	3.822	Volatile matter in soot 13.904, carbon 50.84 per cent.
14.00	5.46	43.25	17.083	1.922	
34.87	4.91	35.72	14.800	3.999	Volatile matter in soot 13.281, carbon 50.449 per cent.
-	-	-	43.250	-	Two preliminary trials only, to test the working of apparatus, were made with this coal.
19.50	5.12	34.58	5.689	1.255	Volatile matter in soot 10.608, carbon 49.536 per cent.
6.25	3.96	30.91	5.937	1.325	
8.75	3.82	39.85	3.750	1.069	
18.25	3.92	28.31	11.062	2 009	
16.25	3.70	26.96	10 690	2.521	
24.37	8.65	45 33	5.750	2.827	
1.75	10.57	62 35	9 870	0.311	
14.62	3 29	23.26	6 375	1.004	
1.75	8.67	48.11	-	0.806	

TABLE CXCI.

Effect on the evaporative power of the unit of combustible matter, produced by closed and open air plate at the furnace bridge.

Names of coals.	AIR PLATE CLOSED.			AIR PLATE OPEN.			Gain or loss in lbs. to one of combustible by open air plate: (+gain, —loss.)	Per centage gain or loss by open air plate. (+gain, —loss.)
	Number of trials.	Inches opening of damper.	Pounds of water evaporated by 1 lb. of combustible matter of the fuel.	Number of trials.	Inches opening of damper.	Pounds of water evaporated by 1 lb. of combustible matter of the fuel.		
Beaver Meadow, slope No. 3 - - -	2	10 & 5	10.3203	2	10 & 5	10.6028	+0.2825	+ 2.737
Beaver Meadow, slope No. 5 - - -	2	10 & 5	10.7181	2	10 & 5	10.4660	—0.2521	— 2.351
Forest Improvement - - - -	3	8	10.8108	(5 rows open.) 1	8	10.7963	—0.0145	— 0.134
Peach Mountain - - - -	2	8	11.1627	1	8	11.0725	—0.0902	— 1.237
Lehigh - - - - -	2	8	9.7529	1	8	9.2288	—0.5241	— 5.370
Lackawanna - - - - -	3	12, 12, & 10	10.7426	1	5	10.8278	+0.0852	+ 0.793
Lyken's Valley - - - -	2	8 & 4	10.4918	(half open.) 1	8	11.3888	+0.8970	+ 8.550
Natural coke - - - - - -	2	10 & 5	10.1877	(half open.) 2	10 & 5	10.5901	+0.4024	+ 3.958
New York and Maryland Mining Company -	1	8	11.3330	1	8	11.0927	—0.2203	— 1.946
Neff's - - - - - -	2	8	10.9040	2	8	10.3037	—0.6003	— 5.505
Atkinson & Templeman's - - -	1	8	11.5997	1	8	11.6484	+0.0487	+ 4.192
Easby & Smith's - - - -	4	8, 8, 4, & 8	10.9787	1	8	11.2573	+0.2786	+ 2.532
Dauphin and Susquehanna - - -	2	8 & 4	10.9842	1	8	11.5440	+0.5598	+ 5.096
Blossburg - - - - -	2	10 & 5	10.8163	2	10 & 4	11.0952	+0.2789	+ 2.578
Lycoming Creek - - - -	1	10	10.6910	(open and half open.) 2	10	10.7399	+0.0489	+ 0,457
Quin's Run - - - - -	1	8	11.1675	1	8	11.3822	+0.2147	+ 1.922
Barthaus - - - - -	1	12	9.2322	2	12	10.1052	+0.8730	+ 9.456

Cambria County - - - -	1	8	10.0631	2 (7 rows open.)	12	10.4140	+0.3509	+ 3.487
Barr's Deep Run - - - -	3	8	10.3517	1 (open, & 1 half open.)	8	9.8283	--0.5234	-- 5.056
Crouch & Snead's - - - -	2	6	9.5968	2	12 & 6	9.8838	+0.2870	+ 2.990
Midlothian, (900 feet shaft) - - -	1	8	9.7817	2	8	9.5261	--0.2556	-- 2.613
Creek Coal Company - - - -	2	10 & 5	8.5217	2	10 & 5	9.8014	+1.2797	+15.017
Clover Hill - - - -	2	12	8.8831	2	12	8.2939	--0.5892	-- 6.632
Chesterfield Mining Company - - -	1	6	9.7918	3	6 & 12	9.9507	+0.1589	+ 1.623
Midlothian, (average) - - - -	2	12	9.7518	3	6, 12, & 12	9.7666	+0.0148	+ 0.151
Tippecanoe - - - - -	2	12	8.1903	3	8	8.8451	+0.6547	+ 7.993
Midlothian, (new shaft) - - -	1	8	9.5816	2	8	9.8358	+0.2542	+ 2.653
Midlothian, (screened) - - - -	2	12 & 6	9.7669	3	12, 6, & 8	10 1059	+0.3390	+ 3.471
Pictou, (New York) - - - -	2	8 & 4	9 5242	2	8 & 4	9.8955	+0.3712	+ 3.898
Sidney - - - - -	1	8	8.6535	1	8	8.3413	--0.3122	-- 3.608
Pictou, (Cunard) - - - -	1	8	9.7589	1	8	9.5373	--0.2216	-- 2.271
Liverpool - - - - -	1	8	8.3020	2	8	8.7169	+0.4149	+ 4.998
Newcastle - - - - -	1	8	9.2579	2	8	9.5261	+0.1642	+ 1.775
Scotch - - - - -	2	8	7.7296	1	8	8.1571	+0.4275	+ 5.531
Cannelton, (Indiana) - - - -	1	8	7.2495	1	8	8.2183	+0.9688	+12.364

In the remarks appended to or following several of the tables of deductions, will be found some discussions of the influence of open air plates, as modified by other circumstances under which the experiments were conducted. The advantage to the 7 anthracites of using open air plates was, from the above table, on an average 0.43 per cent.; to 10 free-burning coals, 2.13; to 10 Virginia coals, 1.96; and to 6 foreign and 1 western, 3.38 per cent.

TABLE CXCII.—*Effect of open air plate on the rate of evaporation in the boiler when using different kinds of coal.*

Names of coals.	No. of trials with closed air plate.	Inches opening of damper.	Cubic feet of water evaporated per hour with closed air plate.	No. of trials with open air plate.	Inches opening of damper.	Cubic feet of water evaporated per hour with open air plate.	Cubic feet gained or lost by open air plate: (+*gain*, —*loss*.)	Per centage gained or lost by open air plate: (+*gain*, —*loss*.)
Beaver Meadow, slope No. 2 -	2	10 & 5	12.703	2	10 & 5	12.903	+0.662	+ 5.412
Beaver Meadow, slope No. 5 -	2	10 & 5	12.241	2	10 & 5	8.620	—4.083	—32.145
Forest Improvement - -	2	8	15.087	1	8	12.200	—2.887	—19.138
Peach Mountain - - -	2	8	16 050	1	8	13.029	—3.021	—18.822
Lehigh - - - -	2	8	11.155	1	8	8.896	—2.259	—20.250
Lyken's Valley - - -	1	8	13.750	1	8	13.034	—0.616	— 4.480
Natural coke - - -	2	10 & 5	12.510	2	10 & 5	12.613	+0.103	+ 1.215
New York and Maryland Mining Company - - -	1	8	13.100	1	8	12.490	—0.610	— 4.656
Neff's - - - -	1	8	16.958	1	8	13 021	—3.937	— 6.916
Atkinson & Templeman's - -	1	8	16.057	1	8	15 340	—0.717	— 4.465
Easby & Smith's - - -	3	8	14.973	1	8	15.270	+0.297	+ 1.984
Dauphin and Susquehanna -	1	8	14.824	1	8	13.600	—1.224	— 8.257
Blossburg - - -	*2	10 & 5	17.275	*2	10 & 4	14.070	—3.205	—18.553
Lycoming Creek - - -	1	10	12.700	1	10	13.660	+0.960	+ 7.559
Quin's Run - - -	1	8	13.749	1	8	14.050	+0.301	+ 2.189
Karthaus - - - -	1	12	11.857	3	12	12.689	+0.832	+ 7.022
Barr's Deep Run - - -	3	8	13 841	1	8	12.791	—1.049	— 7.584
Midlothian, (900 feet shaft) -	1	8	13.899	2	8	14.821	+0.922	+ 6.634
Creek Coal Company - -	†2	5 & 10	12.822	†2	10 & 5	16 948	+4.126	+32 179
Clover Hill - - -	2	12	9.300	1	12	6.884	—2.416	—25.979
Chesterfield Mining Company -	1	5	11.610	1	5	11.390	—0.220	— 1.895
Midlothian, (average) - -	1	12	12.060	1	12	8.779	—3.281	—21.610
Tippecanoe - - -	2	12	8.558	2	8	9.529	+0.971	+11.345
Midlothian, (new shaft) - -	1	8	15.120	1	8	14.180	—0.940	— 6.217
Midlothian, (screened) - -	2	12 & 6	9.118	3	6 & 12	9.100	—0.018	— 0.190
Pictou, (New York) - -	2	8 & 4	12.746	2	8 & 4	12.835	+0.088	+ 0.694
Sidney, (Cunard) - -	1	8	14.790	1	8	12 920	—1.870	—12.644
Pictou, (Cunard) - - -	1	8	17 960	1	8	14 987	—2.973	—16.554
Liverpool - - - -	1	8	16 616	2	8	14.874	—0.741	— 4.748
Newcastle - - -	1	8	16.010	2	8	14.160	—1.850	—11.556
Scotch - - - -	2	8	15.053	1	8	14.769	—0.284	— 1.887
Cannelton, (Indiana) - -	1	8	14.545	1	8	15.551	+1.006	+ 6.916

* The two experiments with closed air plates were made before those with them open.

† The two experiments with open air plates were made before the other two, and while the outside of the boiler was more nearly free from soot than when using the closed plate.

From the last column of the above table, it appears that the average diminution of activity or loss of useful effect in a given time by the boiler, was, for anthracites, 14.9 per cent.; for 8 free-burning coals, 2.68; for 9 Virginia coals, 1.48; and for 6 foreign and 1 western, 5.37 per cent.; making the average, for 31 kinds of coal, 5.37 per cent. A considerable positive gain, both in economy of fuel and in the time of the boiler, was effected, as appears from the above and the preceding table, by using the air plate open in the particular cases of the Karthaus, Creek Company's, Tippecanoe, and Cannelton coals.

TABLE CXCIII.

Observations on the time required by the products of combustion to pass from the grate to the chimney top, being a distance of 103.5 feet by the lower, and 168 by the upper damper passage, before the chimney was raised; and 125.5 by the lower, and 190 by the upper passage, after that addition.

Date.	Hour.	Temperature of air outside of chimney, in degrees Fahrenheit.	Temperature of gases entering chimney, in degrees Fahrenheit.
	h. m.		
May 2	11.20	60.5	270
	4.20	64	452
3	3.00	60.5	206
5	10.00	66	232
9	4.00	63	254
10	2.50	56.5	328
12	4.15	72	[illegible]
13	10.00	67	344
	11.15	69	350
	1.35	73.5	[illegible]
16	5.30	63	260
17	10.30	69.5	262
	0.20	68	294
	2 45	[illegible]	305
20	11.00	[illegible]	317
23	4.50	82	266
	7.00	76	264
24	11.25	75	[illegible]
	5.55	81	313
25	9.45	68	420
	2.00	[illegible]	474
26	7.30	72	372
	[illegible]	76	470
	11.30	79	472
27	9.25	74	288
	10.30	76	306
	11.00	77	310
	11.30	76	308
	0.00	81	310
	0.45	79	306
See note	below.		
May 31	9.00	61.5	302
	0.00	61	310
	0.30	61.5	310
	1.00	64	[illegible]
	1.40	62	316
June 1	8.00	55	280
	8 30	57	302
	10.00	60	300
	10.55	59	314
	3.30	67	322
2	7.30	57	512
	10.00	[illegible]	Ther. burst above 670°.
	11.30	64	

After May 27, the stack, previously 41 feet high, was raised 22 feet $0\frac{3}{8}$ inch, and continued of this height to the end of experiments.

TABLE CXCIII—Continued.

Date.	Hour.	Time occupied by smoke in reaching top of chimney, in seconds.	Inches opening of damper. U. upper; L. lower.	Height of water in syphon, in inches.	Height of barometer, in inches.	Temperature of air outside of chimney, in degrees Fahrenheit.	Temperature of gases entering chimney, in degrees Fahrenheit.
	h. m.						
June 2	1.00	13	L. 6	0.40	30.20	67	
3	0.10	18	U. 6	0.30	29.90	78	328
	1.00	19.5	6	0.26	29.87	81	318
	1.10	20.5	6	0.26	29.87	82	318
	2.00	24	6	0.23	29.86	82	328
	5.15	20	6	0.26	29.88	77	318
6	7.15	11	12	1.80 ?	29.89	74	252
	9.20	15	12	0.44	29.92	73	363
	9.30	12.5	12	0.45	29.92	74.5	374
	9.40	13	12	0.44	29.92	75	364
7	10.50	26.5	6	0.24	30.23	76	325
	11.00	24.5	6	0.24	30.23	76	325
	11.25	23	6	0.23	30.23	76.5	324
	1.45	22	6	0.23	30.22	82	332
8	8.30	30	6	0.20	30.22	76	280
	0.00	32	6	0.18	30.19	84.5	318
	0.30	18	6	0.21	30.16	85	322
	1.00	22	6	0.20	30.16	85	340
9	9.27	16.5	12	0.28	29.99	83	425
	9.50	20	12	0.29	30.00	85	376
12	11.15	15.5	10	0.40	30.21	75	334
13	9.15	22	5	$\left\{\begin{array}{l}0.23\ ?\\0.36\ ?\end{array}\right.$	29.99	72	288
14	2.20	20	5	0.28	29.71	91	334
15	10.00	15.5	10	0.31	29.97	83	384
	1.15	24.5	10	0.28	29.97	88	362
17	10.00	18	10	0.40	30.03	83	288
27	0.00	15	L. 8	0.24	30.12	98	274
	0.10	29	U. 8	0.24	30.12	98	274
Aug. 19	11.00	18	8	0.30	30.01	88	296
21	0.00	20	8	0.32	30.06	80	323
23	0.30	17.5	8	0.35	30.06	84	388
25	11.15	20	8	0.40	30.16	87	331
26	9.30	16	8	0.40	30.18	85	355
	9.45	16	8	0.40	30.18	85	356
28	9.00	24	4	0.21	30.12	84	274
29	0.00	18.5	8	0.33	30.21	87	336
Sept. 6	0.00	18	8	0.36	30.15	86	304
7	11.30	18	8	0.37	30.07	86	374
9	11.30	14 ?	8	0.39	30.13	84	420
13	2.30	19	8	0.34	30.16	72	328
15	2.30	22	4	0.30	29.88	87	308
Oct. 12	9.08	17	8	0.40	29.89	69	347
Aug. 30	0.30	18	8	0.31	30.20	89	304
	1.00	21.5	8	0.25	30.17	89	290
31	11.00	17.5	8	0.35	30.10	91	372
Sept. 1	0.30	23.5	4	0.24	30.09	91	311
2	11.30	26.5	4	0.26	30.10	90	300
Oct. 16	11.00	18.5	8	0.39	29.96	65	336
18	9.30	20	6	0.32	30.01	55	314
Nov. 11	2.00	12.5	8	0.41	29.50	70	316
	2.10	14	8	0.41	29.50	70	317
	2.15	8.5	L. 8	0.41	29.51	70	318
	2.25	8	8	0.41	29.51	70	319

TABLE CXCIV—Part I—*Exhibiting the analyses, proportions, and heat-absorbing powers of gases from combustion.*

Designation of coal.	Data, by observation.														Relations of the chief products of combustion.					
															Water.				Carbonic acid collected.	
	Number of trial	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer, in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temp. of air at mercurial bath, in degrees Fahrenheit.	Diff. of temp. betw. escaping gases & air entering below ash pit—deg. F.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temp. and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Grains of, in 100 cub. in. of atmos. air, at dew point.	Grains of, derived from combustion.	Bulk of oxygen in, from combustion, in cubic inches.	Grains of hydrogen in, from combustion.	Cubic inches at standard temperature and pressure.	Grains of carbon in.
					h. m.															
Beaver Meadow, slope No. 3.	1	June 28	Closed.	10	0.53 p. m.	12	29.886	78	175	71.1	100	0.72	4.40	15.150	.473	.2063	0.6270	.0229	9.310	1.2198
	1	" 28	Closed.	10	5.28 p. m.	13	29 834	82	173	72.4	100	0.68	5.68	8.611	.494	.1313	0.3990	.0146	12.018	1.5734
	2	" 29	Closed.	5	3.08 p. m.	21	29.836	85	160	70.0	100	0.75	5.46	12.880	.459	.2471	0.7506	.0275	11.553	1.5124
Forest Improvement.	2	Aug. 5	Open.	8	1.07 p. m.	16	30.100	90	190	74.8	80	0.51		0	.531	.0620	0.1884	.0069	7.088	0 9279
	3	" 7	Closed.	4	0.42 p. m.	25	30.019	87	151	71.9	80	0.68		3	.583	.2130	0.6472	.0237	9.163	1.1994
	4	" 8	Closed	8	2.40 p. m	36	29.978	84	202	74.9	80	1.00		7	.588	.5333	1.6210	.0593	8.591	1.1246
Peach Mountain	1	Aug. 10	Closed.	8	0.36 p. m.	24	29.972	76	210	71.0	60	0.57		0	.473	.1554	0.4721	.0173	8.146	1.3435
	2	" 11	Closed.	8	0.46 p. m.	21	29.908	84	213	72.1	80	0 66	5.62	10.306	.489	.2174	0.6605	.0242	11.892	1.5567
	3	" 12	Open.	8	0.07 p. m.	28	30 015	85	208	70.0	100	0.81	4.86	13.498	.459	.3157	0.9593	.0351	10.283	1.3462

TABLE CXCIV—Part I—Continued.

Designation of coal.	Relations of the chief products of combustion.						Deductions relative to heating power of fuel.							
	Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Ratio to total bulk of dry gases, per cent. of the—			Grains of raw coal, equivalent to the carbon and hydrogen collected.	Atmospheric air, at standard temperature and pressure.				Pounds of water, equivalent in specific heat to the dry gases from 1 lb. of fuel.	Water of combustion from 1 lb. of fuel, in pounds.	Hygrometric moisture in the air required for 1 lb. of fuel, in pounds.
				Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.		Weight of, equivalent to the dry gases, in grains.	Bulk of, required for 1 lb. of fuel, in cubic feet.	Pounds of, required for 1 lb. of fuel.	Pounds of, equal in specific heat to dry gases from 1 lb. of fuel.			
Beaver Meadow, slope No. 3	82.329	14.700	106.339	8.755	13.824	22.579	1.39006	32.9765	309.89	23.724	24.283	6.481	0.14841	0.37292
	88.174	8.308	108.500	11.077	7.657	18.734	1.77630	33.6478	247.44	18.943	19.508	5.207	0.07392	0.31275
	83.589	12.357	107.499	10.747	11.496	22.242	1.79819	33.3373	242.85	18.591	19.129	5.106	0.13780	0.28679
Forest Improvement	65.699	11.088	82.875	8.451	13 220	21.671	1.02335	26.0111	332.02	25.418	25.996	6.938	0.06058	0.45364
	68.391	7.619	85.173	10.757	8.945	19.703	1.36260	26.4137	253.21	19.385	29.947	5.324	0.15632	0.35032
	67.604	8.929	85.124	10.092	10.490	20.582	1.30434	26.3984	264.27	20.239	20.789	5.549	0.40887	0.36314
Peach Mountain	67.240	10.449	85.835	9.490	12.174	21.664	1.48048	26.6189	234.86	17.980	18.440	4.922	0.10493	0.28209
	68 669	7.890	88.451	13.445	8.920	22.365	1.73515	27.4302	206 50	15.809	16.376	4.371	0.12529	0 26034
	82.500	12.873	105.656	9.724	12.202	21.916	1.52484	32.7658	280.69	21.488	22.050	5.885	0.20704	0.33347

TABLE CXCIV—Part I—Continued.

Designation of coal.	Deductions relative to heating power of fuel.					Remarks.
	Pounds of steam from water, at 212°, to 1 lb. of fuel, equivalent to heat imparted to				Total calculated evaporative power to 1 of fuel, in steam from 212°.	
	I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.		[N. B.—In this table are presented all those experiments on the composition of the gases in which the series of observations was complete In the daily ... rill be found some 25 or 30 other trials, in which only ... s were ascertained; they serve to confirm, so far as ... ts of these, in regard to the varying proportion of the ... ustion while burning the same fuel.]
Beaver Meadow, slope No. 3	1.1012	0.17363	0.06336	9.5029	10.851	Dew point, at 9h. 30m. a. m , by calculation, 71°.7; by observation, 71°.5.
	0 8745	0.08633	0.05253	9.5029	10.516	At 4h. 10m. p. m., dew point, by calculation, 72°.4; by observation, 72°.7. A heavier bed of coal on the grate than during the first drawing of gas.
	0.7931	0.16254	0.04455	8.9126	9.913	Dew point, at 8h. 30m. ... 70°; by observation, 69°.8. At 2h. 30m. p. m., by ... observation, 68°.7.
Forest Improvement	1.2800	0.71762	0.06368	10.0617	12.133	Tested for [illegible]gen a second time, with same result.
	0.7960	0.17969	0.05238	9.2064	10.234	At 11h. 30m. a. m., dew point, by observation, 74°; by calculation, 77°.2. This result is probably too low, on account of the production of some carbonic oxide.
	1.0682	0.46905	0.07122	10.3734	12.021	
Peach Mountain	1.0035	0.12632	0.05751	10.2740	11.461	Fifty-seven cubic inches of gas in jar repassed through potass; no additional absorption.
	0.9039	0.15120	0.05364	10.5790	11.686	
	1.1864	0.24865	0.06734	10.2407	11.745	A portion of gas in jar repassed through chloride of calcium and oxide of copper: result allowed for in table.

TABLE CXCIV—PART II.

Designation of coal.	Data, by observation. Number of trial.	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer, in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temperature of air at mercurial bath, in degrees Fahrenheit	Diff. of temp. betw. escaping gases and air entering below ash pit—deg. F.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temperature and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Relations of the chief products of combustion. Water. Grains of, in 100 cub. in. of atmos. air, at dew point.	Water. Grains of, derived from combustion.	Water. Bulk of oxygen in, from combustion, in cubic inches.	Water. Grains of hydrogen in, from combustion.	Carbonic acid collected. Cubic inches at standard temperature and pressure.	Carbonic acid collected. Grains of carbon in.
					h. m.															
Beaver Meadow, slope No. 5.	2	July 7	Closed.	5	1.15 p. m.	15	29.915	85	177	70 6	105	0.90	4.96	13.873	.462	.3769	1.1450	.0419	10.495	1.3739
	3	" 8	O. 5 rows.	10	4.38 p. m.	12	29 905	85	195	62.2	60	0.37	2.99	14 440	.358	.1427	0.4338	.0159	6.326	0.8282
	4	" 10	O. 5 rows.	5	0.22 p. m.	28	29.809	84	161	71.5	100	0.96	3.35	16.390	.481	.4522	1.3740	.0502	7.088	0.9279
	4	" 10	O. 5 rows.	5	4.24 p. m.	31	29.766	85	155	72.5	100	0.84	2.46	19.090	.492	.3291	0.9997	.0366	5.205	0.6814
Lehigh - -	4	Nov. 3	Removed.	10	11.04 a. m.	79	30.163	49	259	32.8	100	0.00	2.32	17.500	.136	-.1384	-.4205	-.0154	4.909	0.6426
Lackawanna -	4	July 14	Open.	5	4.35 p. m.	15	30.147	81	176	70.0	100	0.69	5.36	12.120	.459	.1894	0.5758	.0210	11.341	1.4847
Natural coke -	1	June 17	Closed.	10	3.50 p. m.	10	29.985	75	174	63.7	100	0 70	4.50	11.110	.382	.3492	1.0610	.0388	9.522	1.2465
	2	" 19	Open.	10	11.05 a. m.	10	30.214	72	199	53 4	60	0.43	2.67	12.770	.274	.2572	0.7815	.0286	5.649	0.7396
	2	" 19	Open.	10	0.32 p. m.	12	30.215	75	196	53.7	80	1.03	3 76	15.220	.276	.7992	2.4290	.0888	7.448	1.0415
	2	" 19	Open.	10	3.32 p. m.	13	30.196	78	198	54.2	100	0 82	4.86	12.120	.279	.5267	1.6010	.0585	10.283	1.3462
	3	" 20	Open.	5	11.42 a. m.	14	30.318	77	204	58.5	100	0.76	4.17	14.440	.321	.4250	1.2920	.0472	8.823	1.1551
	4	" 21	Closed.	5	0.33 p. m.	13	30.186	81	196	59.9	101	1.17	5.44	14.440	.337	.8061	2.4500	.0896	11.511	1.5069

TABLE CXCIV—Part II—Continued.

Designation of coal.	Relations of the chief products of combustion.						Deductions relative to heating power of fuel.							
	Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Ratio to total bulk of dry gases, per cent. of the—			Grains of raw coal, equivalent to the carbon and hydrogen collected.	Atmospheric air, at standard temperature and pressure.				Pounds of water, equivalent in specific heat to the dry gases from 1 lb. of fuel.	Water of combustion from 1 lb. of fuel, in pounds.	Hygrometric moisture in the air required for 1 lb. of fuel, in pounds.
				Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.		Weight of, equivalent to the dry gases, in grains.	Bulk of, required for 1 lb. of fuel, in cubic feet.	Pounds of, required for 1 lb. of fuel.	Pounds of, equal in specific heat to dry gases from 1 lb. of fuel.			
Beaver Meadow, slope No. 5 -	96.538	13.939	110.972	9.457	12.561	22.018	1.54085	34.4143	291.75	22.335	22.904	6.113	0.24460	0.34771
	49.141	8.294	63.761	9.922	13.007	22.929	0.90987	19.7734	283.88	21.732	22.313	5.955	0.15684	0.26208
	80.440	15.769	103.297	6.862	15.265	22.128	1.07001	32.0342	391.08	29.939	30.493	8.138	0.42262	0.48266
	77.812	18.359	101.376	5.134	18.110	23.244	0.78546	31.4384	522.84	40.026	40 579	10.831	0.41899	0.66029
Lehigh - - - -	84.552	17.936	107.397	4.571	16.700	21.272	0.69514	33.3057	625.85	47.912	48.502	12.945	-	0.20501
Lackawanna - - -	84.063	11.594	106.998	10.599	10.835	21.435	1.76830	33.1820	253.73	19.424	19.978	5.332	0.11087	0.29491
Natural coke - - -	86.446	10.805	106.773	8.918	10.119	19.037	1.62318	33.1122	266.47	20.399	20.889	5.575	0.21513	0.25838
	50.798	7.437	63.884	8.843	11.641	20.484	0.93387	19.8119	277.12	21.215	21.720	5.797	0.27541	0.19312
	65.457	11.751	84.656	8.798	13.881	22.679	1.37438	26.2533	249.58	19.106	19 559	5.220	0.58150	0.17619
	84.394	11 639	106.316	9.660	10.959	20.619	1.70763	32.9705	252.21	19.308	19.810	5.287	0.30844	0.18088
	81.988	13.837	104.648	8.430	13.224	21.658	1.53480	32.4532	276.20	21.145	21 625	5.772	0.27692	0.22840
	82.555	13.933	107.999	10.659	12.901	23.560	1.97029	33.4924	222.05	16.999	17.487	4.667	0.40918	0.19836

TABLE CXCIV—Part II—Continued.

Designation of coal.	Deductions relative to heating power of fuel. Pounds of steam from water, at 212°, to 1 lb. of fuel, equivalent to heat imparted to: I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.	Total calculated evaporative power, to 1 of fuel, in steam from 212°.	Remarks.
Beaver Meadow, slope No. 5 -	1.0505	0.28664	0.05975	10.1002	11.497	Dew point, at 4*h*. 50*m*., by calculation, 72°; by observation, 71°.5.
	1.1275	0.18654	0.04962	10.1819	11.545	
	1.2722	0.48867	0.07779	9.2870	11.125	
	1.6298	0.48204	0.09936	9.2870	11.498	Gas drawn from upper flue.
Lehigh - - - -	3.2552	-	0.05155	8.9747	12.281	Ash pit doors open; combustion rapid; syphon 0.40 to 0.54.
Lackawanna - - -	0.9111	0.12982	0.05039	9.6099	10.701	
Natural coke - - -	0.9418	0.25380	0.04365	7.9894	9.238	Gas in jar produced blueness in flame of candle, (carbonic oxide.)
	1.1200	0.32863	0.03781	8.7038	10.189	
	0.9934	0.69215	0.03353	8.7038	10.423	Fire blazing.
	1.0469	0.36773	0.03477	8.7038	10.152	Fire very active; constantly blazing.
	1.1431	0.33177	0.04524	8.5414	10.061	
	0.8881	0.48698	0.03680	8.6566	10.068	

TABLE CXCIV—Part III.

Designation of coal.	Data, by observation.														Relations of the chief products of combustion.					
															Water.				Carbonic acid collected.	
	Number of trial.	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer, in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temperature of air at mercurial bath, in degrees Fahrenheit.	Diff. of temp. betw. escaping gases & air entering below ash pit—deg. F.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temperature and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Grains of, in 100 cubic in. of atmos. air, at dew point.	Grains of, derived from combustion.	Bulk of oxygen in, from combustion, in cubic inches.	Grains of hydrogen in, from combustion.	Cubic inches at standard temperature and pressure.	Grains of carbon in.
					h m.															
Coke of Midlothian	-	Nov. 6	Closed.	8	11.52 a. m.	50.5	30.308	44.0	249	29.5	100	0.56	7.44	9.167	.124	0.4341	1.3190	.0482	15.742	2.0609
Atkinson & Templeman's.	1	Sept. 21	Open.	8	0.28 p. m.	36.0	30 072	86.0	210	78.0	100	2.15	4.53	14.070	.585	1.5112	4.5920	.1679	9.585	1.2548
	2	" 22	Closed.	8	11.05 a. m.	27.0	29.977	84.5	244	70.0	100	1.36	6.05	11.030	.459	0.8509	2.5860	.0945	12.801	1.6758
New York and Maryland Mining Co.	1	Sept. 18	Closed.	8	11.50 a. m.	25.0	30.049	87.0	197	76.0	100	1.59	5.89	9.444	.551	0.9755	2.9640	.1084	12.462	1.6315
	1	" 18	Closed.	8	1.40 p. m.	25 5	30.033	89.0	185	77 3	100	3.06	5.08	12.777	.573	2.4317	7.3890	2702	10.749	1.4072
	2	" 19	Open.	8	11.05 a. m.	29.5	30.166	88.0	208	76.6	100	1.58	6.50	10.209	.561	1 2449	3.7810	.1383	13.758	1.8005
Easby's Coal-in-Store	-	Sept. 25	Open.	8	11.40 a. m.	30 0	29.887	88.0	180	72.0	100	1.52	4.71	11.870	.488	0.9956	3.0260	.1106	9 967	1.3047
	-	" 25	Closed.	8	1.20 p. m.	24.0	29.831	90.0	186	74.0	100	1.16	3.72	11.760	.517	0.6160	1.8720	.0684	7.871	1.0304
Easby & Smith's	5	Nov. 16	Closed.	8	0.34 p. m.	46.0	30.133	59.0	221	53.6	100	0.72	9.07	10.000	.274	0.3958	1.2030	.0440	19.191	2.5124

TABLE CXCIV—Part III—Continued.

Designation of coal.	Relations of the chief products of combustion: Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Ratio to total bulk of dry gases, per cent. of the— Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.	Deductions relative to heating power of fuel: Grains of raw coal, equivalent to the carbon and hydrogen collected.	Atmospheric air, at standard temperature and pressure: Weight of, equivalent to the dry gases, in grains.	Bulk of, required for 1 lb. of fuel, in cubic feet.	Pounds of, required for 1 lb. of fuel.	Pounds of, equal in specific heat to dry gases from 1 lb. of fuel.	Pounds of water, equivalent in specific heat to the dry gases from 1 lb. of fuel.	Water of combustion from 1 lb. of fuel, in pounds.	Hygrometric moisture in the air required for 1 lb. of fuel, in pounds.
Coke of Midlothian	92.759	9.361	117.862	13.357	7.943	21.299	2.52723	36.5510	188.92	14.463	14.983	3.999	0.17177	0.05629
Atkinson & Templeman's	82.468	13.503	105.556	9.081	12.792	21.873	1.64580	32.7347	259.81	19.890	20.377	5.439	0.91822	0.39094
	85.323	10.578	108.702	11.777	9.731	21.508	2.01849	33.7104	218.15	16.701	17.230	4.599	0.42155	0.25775
New York and Maryland Mining Company.	86.700	9.042	108.204	11.517	8.357	19.874	2.16643	33.5559	202.33	15.489	15.969	4.262	0.45028	0.28745
	83 195	12.187	106.131	10.128	11.483	21.611	2.08860	32.9180	205.85	15.758	16.188	4.321	1.16427	0.30527
	86.161	9.796	109.710	12.536	8.929	21.465	2.13758	34.0230	207.91	15.917	16.455	4.392	0.58266	0.30096
Easby's Coal-in-Store	83.783	11.285	105.035	9.489	10.743	20.233	1 55620	32.5732	273.42	20.931	21.466	5.729	0.63976	0.34647
	83.462	11.123	102.456	7.682	10.857	18.539	1.20820	31.7734	343.52	26.298	26.842	7.164	0.50985	0.46352
Easby & Smith's	90.555	10.062	119.808	16.019	8.398	24.417	2.83574	37.1546	171.15	13.102	13.667	3.648	0.13957	0.11506

TABLE CXCIV.—Part III—Continued.

Designation of coal.	Deductions relative to heating power of fuel.					Remarks.
	Pounds of steam from water, at 212°, to 1 pound of fuel, equivalent to heat imparted to				Total calculated evaporative power to 1 of fuel, in steam from 212°.	
	I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.		[N. B.—In the case of the bituminous coals embraced in this part of the table, and of all others of the same class, some uncertainty must necessarily attend production of the variable amount during the com- 3 gallons of am- per gallon, give
Coke of Midlothian	0.9667	0.21329	0.01369	8.6319	9.825	This coke gave 16.546 per cent. of waste; hence the evaporative power of 1 of its combustible is 11.773.
Atkinson & Templeman's	1.1088 1.0894	1.10543 0.58142	0.07971 0.08106	10.7070 10.6913	13.000 12.368	Tested atmospheric air: gave 21.32 per cent. oxygen.
New York and Maryland Mining Company.	0.8152 0.7760 0.8869	0.53641 1.37369 0.70089	0.05500 0.05483 0.06059	9.2956 9.2956 10.2582	10.702 11.499 11.907	Excess of water probably from iron tube, condensed in previous trial. Oxygen, the mean of three trials.
Easby's Coal-in-Store	1.0012 1.2937	0.75157 0.60192	0.06055 0.08730	10.0188 10.0188	11.881 12.001	
Easby & Smith's	0.7827	0.16962	0.02469	9.9233	10.900	

TABLE CXCIV—Part IV.

Designation of coal.	Data, by observation.														Relations of the chief products of combustion.					
															Water.				Carbonic acid collected.	
	Number of trial.	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer, in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temperature of air at mercurial bath, in degrees Fahrenheit.	Difference of temperature between escaping gases and air entering below ash pit, in degrees Fahrenheit.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temperature and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Grains of, in 100 cub. in. of atmospheric air, at dew point.	Grains of, derived from combustion.	Bulk of oxygen in, from combustion, in cubic inches.	Grains of hydrogen in, from combustion.	Cubic inches at standard temperature and pressure.	Grains of carbon in.
					h. m.															
Neff's	3	Oct. 17	Open.	12	10.27 a. m.	25	29.959	57.0	299	39.4	100	0.95	5.99	10.145	.174	.7610	2.3130	.0845	12.674	1.6592
	3	" 17	Closed.	12	11.49 a. m.	29	29.946	58.0	299	41.1	100	0.67	4.54	13 750	.184	4760	1 4460	.0529	9.606	1.2576
Dauphin and Susquehanna.	1	July 27	Closed.	8	0.30 p. m.	25	30.018	94.0	170	73.3	100	1.22	4.76	12.220	.518	.6677	2.0290	.0742	10.072	1 3185
	2	" 28	Open.	8	0 12 p. m	56	29.954	92.0	200	73.2	80	1.04	4.21	11.110	.506	.6023	1 8300	.0669	8.908	1.1662
	3	" 29	Closed.	4	0.18 p m	21	29.867	94.5	158	77.1	80	0.90	4.17	9.074	.569	.4048	1.2300	.0450	8 823	1 1551
Blossburg	4	July 20	Open.	4	11.29 a. m.	33	29 956	78.0	220	54.9	101	0.77	5.24	12.413	.280	.4684	1.4240	.0520	11.087	1.4515
	4	" 20	Open.	4	4.28 p. m.	37	29 915	78.5	232	54.2	100	0.82	4.72	11.939	.279	.5253	1.5960	.0584	9.987	1.3075
Lycoming Creek	1	June 23	Closed.	10	10 22 a. m.	17	30 017	81.0	202	67.5	50	0.44	1.74	15.150	.426	.2167	0.6584	0241	3.682	0.4820
	1	" 23	Closed.	10	0.25 p. m	15	29.988	84.0	194	67.2	100	1.19	5 87	10.000	.422	.7277	2.2110	.0809	12 420	1.6260
	2	" 24	Open.	10	0.41 p m.	16	29 805	82.0	215	72.7	100	1.42	5.47	12.220	.503	.8651	2.6290	.0961	11.151	1.5152
Quin's Run	1	Aug. 1	Closed.	8	0.59 p. m	17	29.956	78.0	206	62.0	80	0.46	4.92	11.888	.369	.1487	0.4520	.0165	8.929	1.1689

TABLE CXCIV—PART IV—Continued.

Designation of coal.	Relations of the chief products of combustion.						Deductions relative to heating power of fuel.							
	Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Ratio to total bulk of dry gases, per cent. of the—			Grains of raw coal, equivalent to the carbon and hydrogen collected.	Atmospheric air, at standard temperature and pressure.				Pounds of water, equivalent in specific heat to the dry gases from 1 lb. of fuel.	Water of combustion from 1 lb. of fuel, in pounds.	Hygrometric moisture in the air required for 1 lb. of fuel, in pounds.
				Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.		Weight of, equivalent to the dry gases, in grains.	Bulk of, required for 1 lb. of fuel, in cubic feet.	Pounds of, required for 1 lb. of fuel.	Pounds of, equal in specific heat to dry gases from 1 lb. of fuel.			
Neff's	90.199	10.184	113 056	11.211	9.008	20.218	2.00263	35.0592	228.69	17.507	18.035	4.813	0.38000	0.09786
	86.392	13.778	109.771	8.751	12.547	21.298	1.50510	34.0120	295.44	22.618	23.151	6.179	0.31626	0.13397
Dauphin and Susquehanna	82.353	11.465	103.890	9.694	11 035	20.730	1.65393	32.2181	254.46	19.480	19.988	5.335	0 40371	0.34682
	67 100	8.386	84.394	10 555	9.937	20.492	1.48070	26.1721	230.89	17.676	18.178	4.852	0.40677	0.30565
	68.596	6.846	85.265?	10 471?	8.124	18.595?	1.46199	26.1320	233.48	17.874	18 378	4.905	0.27688	0.34760
Blossburg	85.616	12.134	108.837	10.187	11.148	21 335	1.73422	33.7523	254.23	19.463	19.996	5.337	0.27166	0 18157
	85.282	11.563	106.832	9.348	10 823	20.171	1.57551	33.1305	274.78	21.029	21.558	5.754	0.33312	0.19542
Lycoming Creek	40.759	7.277	51.718	7.119	14.071	21.190	0.60525	16.0384	346.15	26.499	27 007	7.208	0.35803	0.37890
	86.072	9.563	108.055	11.494	8.851	20.345	2.04130	33.5098	214.44	16.416	16.924	4.517	0.35649	0.23359
	84 774	11.802	107.727	10 351	10.955	21.306	1.93143	33.4080	225.94	17.297	17.779	4.745	0 44791	0 29049
Quin's Run	68.623	8.819	86.371	10.338	10.211	20.549	1.30067	26.7852	269.00	20.593	21.166	5.649	0.11459	0.24627

TABLE CXCIV—Part IV—Continued.

Designation of coal.	Deductions relative to heating power of fuel. Pounds of steam from water, at 212°, to 1 lb. of fuel, equivalent to heat imparted to I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.	Total calculated evaporative power to 1 of fuel, in steam from 212°.	Remarks.
Neff's	1.3903	0.49031	0.02841	9.2222	11.131	
	1.7937	0.40807	0·03889	9.2222	11.462	
Dauphin and Susquehanna	0.8805	0.47033	0.05724	9.2835	10.691	Syphon 0.30 inch at time of drawing gases.
	0.9421	0.48575	0.05935	9.6652	11.152	At 11*h*. 5*m*. a. m., dew point at air port, by calculation, 75°.2; by observ., 73°
	0.7524	0.31935	0.05332	9.0798	10.204	At 11*h*. 0*m*. a. m., dew point in free air, by calculation, 77°.5; by observ., 73° 5.
Blossburg	1.1399	0.30361	0.03878	9.8062	11.288	
	1.2970	0.40852	0.04402	9.8065	11.555	
Lycoming Creek	1.4136	0.42825	0.07431	9.0112	10.927	Furnace in average action. Dew point, by observation, 67°.5; by calculation, 67°.
	0.8508	0.42363	0.04400	9.0112	10.329	Fire burning freely, flame passing off briskly.
	0.9905	0.54140	0.06092	9.1643	10.757	
Quin's Run	1.1299	0.13751	0.04925	10.2711	11.587	

TABLE CXCIV—Part V.

Designation of coal.	Data, by observation.														Relations of the chief products of combustion.					
															Water.				Carbonic acid collected.	
	Number of trial.	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temperature of air at mercurial bath, in degrees Fahrenheit.	Diff. of temp. between escaping gases and air entering below ash pit—deg. F.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temperature and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Grains of, in 100 cubic inches of atmos. air, at dew point.	Grains of, derived from combustion.	Bulk of oxygen in, from combustion, in cubic inches.	Grains of hydrogen in, from combustion.	Cubic inches at standard temperature and pressure.	Grains of carbon in.
					h. m.															
Barr's Deep Run	2	Oct. 24	Open.	8	0.00 m.	33	30.148	57.5	241	40.3	100	0.85	2.71	17.258	.170	0.6755	2.053	0.0751	5 734	0.7507
	3	" 25	Closed.	8	4.46 p m	30.5	29.953	59	277	55.7	100	1.36	4.98	11.875	.294	1.0376	3.153	0.1153	10.537	1.3795
	4	" 27	Open.	8	10.32 a. m.	60	29.638	54	270	45.8	100	0.80	4.53	13.750	.214	0.5725	1.740	0.0636	9.585	1.2548
Midlothian average, (900 feet shaft.)	3	Oct. 12	Open.	8	9.51 a. m.	51	29.877	71	293	61 5	100	0.95	5.96	11.213	.353	0.5593	1.700	0.0621	12 610	1.6509
	3	" 12	Open.	8	0.17 p. m.	37	29.874	72	304	61.6	101	0.80	5.75	11.182	.356	0.4047	1.230	0.0450	12.166	1.5928
Creek Coal Company.	1	June 12	Open.	10	1.30 p. m.	-	30.145	75	298	55.7	60	0.61	1.87	14.390	.297	0.4274	1.299	0.0475	3.957	0.5180
	2	" 13	Open.	5	-	-	29.910	70	254	61.8	60	0.68	4.17	14.440	.359	0.4355	1.323	0.0484	8.823	1.1551
	2	" 13	Open.	5	0.08 p m.	-	29.847	78	259	63.7	60	0.59	2.78	14.390	.382	0.3431	1.043	0.0381	5.882	0.7701
	3	" 14	Closed.	5	1.30 p. m.	10	29.646	85	239	68.8	100	0.98	6.02	10 550	.445	0.4854	1.475	0.0539	12.738	1.6675
Chesterfield Mining Company.	4	June 9	Open.	12	1.03 p. m.	11	29.868	91	286	73 8	100	0.98	3.23	14.440	.519	0.4393	1.335	0.0488	6.884	0.8947

TABLE CXCIV—Part V—Continued.

Designation of coal	Relations of the chief products of combustion.							Deductions relative to heating power of fuel.						
				Ratio to total bulk of dry gases, per cent. of the—				Atmospheric air, at standard temperature and pressure.						
	Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.	Grains of raw coal, equivalent to the carbon and hydrogen collected.	Weight of, equivalent to the dry gases, in grains.	Bulk of, required for 1 lb. of fuel, in cubic feet.	Pounds of, required for 1 lb. of fuel.	Pounds of, equal in specific heat to dry gases from 1 lb. of fuel.	Pounds of water, equivalent in specific heat to the dry gases from 1 lb. of fuel.	Water of combustion from 1 lb. of fuel, in pounds.	Hygrometric moisture in the air, required for 1 lb. of fuel, in pounds.
Barr's Deep Run - -	83.503	17.422	106.659	5.376	16.334	21.710	0.93843	33.0768	460.41	35.247	35.758	9.544	0.71982	0.19144
	88.156	11.880	110.573	9.530	10.743	20.273	1.71757	34.2906	260.79	19.965	20.477	5.465	0.60411	0.22747
	85.990	13.709	109.284	8.771	12.544	21.315	1.49468	33.8909	296.18	22.674	23.209	6.195	0.38302	0.15694
Midlothian average, (900 feet shaft)	86.787	10.960	110.357	11.427	9.932	21.358	1.95751	34.2236	228.38	17.483	18.021	4.810	0.28572	0.20360
	87.528	11.020	110.714	10.989	9.953	20.943	1.87158	34.3347	239.60	18.342	18.884	5.040	0.21623	0.21580
Creek Coal Company - -	49.689	8.352	61.998	6.382	13.472	19.854	0.62163	19.2267	404.01	30.929	31.460	8.397	0.68755	0.30621
	50.521	8.527	67.871	13.000	12.563	25.563	1.33430	21.0480	206.06	15.775	16.327	4.358	0.32639	0.18556
	49.906	8.388	64.176	9.165	13.071	22.236	0.89604	19.9021	290.14	22.211	22.759	6.074	0.38291	0.28161
	86.374	10.187	109.299	11.654	9.321	20.975	1.90470	33.8955	232.46	17.796	18.353	4.898	0.25484	0.26446
Chesterfield Mining Company -	81.396	13.405	101.635	6.724	13.189	19.913	1.06695	31.5188	385.88	29.541	30.076	8.027	0.41174	0.52150

TABLE CXCIV—Part V—Continued.

Designation of coal.	Deductions relative to heating power of fuel.					Remarks.
	Pounds of steam from water at 212°, to 1 lb. of fuel, equivalent to heat imparted to				Total calculated evaporative power to 1 of fuel, in steam from 212°.	
	I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.		
Barr's Deep Run - -	2.2331 1.4698 1.6838	0.88824 0.76657 0.48343	0.04479 0.06117 0.04114	8.9947 9.1905 8.6737	12.160 11.488 10.822	
Midlothian average, (900 feet shaft.)	1.3682 1.4876	0.36700 0.28005	0.05778 0.06400	8.1019 8.1019	9.894 9.933	Ash pit doors open.
Creek Coal Company -	2.4293 1.0743 1.5274 1.1366	0.88647 0.40688 0.47920 0.31398	0.08859 0.01576 0.07081 0.06136	9.2761 8.6582 8.6582 7.7457	12.680 10.185 10.735 9.257	 Smoke flowing from chimney. No smoke from chimney.
Chesterfield Mining Company	2.2289	0.52606	0.01448	8.8637	11.633	No smoke flowing from chimney.

TABLE CXCIV—Part VI.

Designation of coal.	Number of trial.	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer, in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temp. of air at mercurial bath, in degrees Fahrenheit.	Diff. of temp. betw. escaping gases and air entering below ash pit—deg. F.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temp. and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Water. Grains of, in 100 cub. in. of atmos. air, at dew point.	Water. Grains of, derived from combustion.	Water. Bulk of oxygen in, from combustion, in cubic inches.	Water. Grains of hydrogen in, from combustion.	Carbonic acid collected. Cubic inches at standard temperature and pressure.	Carbonic acid collected. Grains of carbon in.
					h. m.															
Midlot'n, (new shaft)	2	Sept. 14	Closed.	8	9.45 a. m.	44.0	30.099	67.0	253.0	64.9	100	0.44	5.19	12.777	.395	.0010	0.0031	.0001	10.981	1.4376
	2	" 14	Closed.	8	11.38 a. m.	38.0	30.080	70.0	253.0	67.1	100	0.69	5.56	8.333	.420	.2203	0.6691	.0245	11.764	1.5401
	3	" 15	Open.	8	0.04 p. m.	30.0	29.852	79.5	212.5	71.4	100	0.69	4.29	13.930	.479	.1743	0.5296	.0194	9.077	1.1827
	3	" 15	Open.	4	5.14 p. m.	28.0	29.815	82.0	212.5	74.6	100	0.70	4.56	12.381	.526	.1300	0.3952	.0144	9.648	1.2631
Tippecanoe -	5	Nov. 14	Open.	8	11.36 a. m.	36.0	30.368	44.0	270.0	29.5	100	1.06	6.04	8.750	.124	.9261	2.8140	.1029	12.780	1.6731
Midlot'n, (screened)	5	Nov. 11	Open.	8	0.32 p. m.	56.0	29.458	64.0	249.0	62.7	100	0.40	5.58	10.000	.370	-.0180	-.0571	-.0021	11.807	1.5457
Sidney - -	1	Sept. 30	Closed.	8	0.42 p. m.	20.0	30.126	68.0	237.0	60.3	100	1.77	5.74	10.928	.340	1.3917	4.2290	.1546	12.145	1.5900
	2	Oct. 2	Open.	8	10.23 a. m.	25.0	29.767	78.0	257.0	59.8	100	0.91	4.94	10.355	.335	.5527	1.6800	.0614	10.452	1.3684
Pictou, (from N. Y.)	1	Aug. 30	Open.	8	11.01 a. m.	34.5	30.140	80.0	193.0	75.5	100	1.18	5.34	9.453	.543	.5188	1.5770	.0576	11.297	1.4792
	2	" 31	Closed.	8	1.52 p. m.	51.0	29.943	92.5	236.0	76.6	100	1.31	5.89	9.798	.561	.6905	2.0980	.0767	12.468	1.6315
	3	Sept. 1	Open.	4	0.52 p. m.	41.5	29.992	86.0	222.0	77.5	100	1.31	5.11	11.250	.576	.6759	2.0540	.0751	10.812	1.4155

Column groups: "Data, by observation." covers the columns from Number of trial to Condensation; "Relations of the chief products of combustion." covers the Water and Carbonic acid collected columns.

TABLE CXCIV—Part VI—Continued.

Designation of coal.	Relations of the chief products of combustion.						Deductions relative to heating power of fuel.							
				Ratio to total bulk of dry gases per cent. of the—				Atmospheric air, at standard temperature and pressure.						
	Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.	Grains of raw coal, equivalent to the carbon and hydrogen collected.	Weight of, equivalent to the dry gases, in grains.	Bulk of, required for 1 lb. of fuel, in cubic feet.	Pounds of, required for 1 lb. of fuel.	Pounds of, equal in specific heat to dry gases from 1 lb. of fuel.	Pounds of water, equivalent in specific heat to the dry gases, from 1 lb. of fuel.	Water of combustion from 1 lb. of fuel, in pounds.	Hygrometric moisture in the air required for 1 lb. of fuel, in pounds.
Midlot'n, (new shaft)	86.471	12.667	110.119	9.972	11.503	21.475	1.60825	34.1498	277.37	21.234	21.805	5.820	0.00622	0.27269
	90.361	8.214	110.339	10.662	7.444	18.106	1.75020	34.2180	255.38	19.551	20.112	5.368	0.12587	0.26861
	82.877	13.413	105.367	8.615	12.730	51.345	1.35169	32.6762	315.78	24.174	24.734	6.601	0.12895	0.38778
	83.916	11.857	105.421	9.152	11.248	20.400	1.43647	32.6929	297.29	22.759	23.320	6.224	0.09050	0.40046
Tippecanoe -	93.000	8.918	114.698	11.142	7.775	18.917	2.00262	35.5699	231.90	17.753	18.286	4.881	0.46245	0.06965
Midloth'n, (screened)	90.958	10.106	112.871	10.460	8.954	19.414	1.75614	35.0032	260.36	19.932	20.493	5.470	-	0.23530
Sidney - -	88.234	10.825	111.204	10.921	9.734	20.656	1.91546	34.4863	235.18	18.004	18.534	4.947	0.72656	0.19927
	86.285	9.967	106.704	9.795	9.341	19.136	1.57727	33.0909	274.05	20.980	21.533	5.747	0.35042	0.23546
Pictou, (from N. Y.)	87.935	9.183	108.435	10.418	8.469	18.887	1.63566	33.6276	239.30	18.319	18.833	5.026	0.28262	0.33022
	85.295	9.265	107.023	11.645	8.657	20.302	2.02144	33.1897	214.47	16.419	16.934	4.520	0.34159	0.31410
	84.949	10.768	106.529	10.149	10.108	20.257	1.76951	33.0365	243.87	18.670	19.180	5.119	0.38197	0.36227

TABLE CXCIV—Part VI—Continued.

Designation of coal.	Deductions relative to heating power of fuel. Pounds of steam from water, at 212°, to 1 lb. of fuel, equivalent to heat imparted to I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.	Total calculated evaporative power to 1 of fuel, in steam from 212°.	Remarks.
Midlothian, (new shaft)	1.4295	0.00774	0.06699	8.6300	10.134	
	1.3185	0.15679	0.06598	8.6300	10.171	
	1.3620	0.15555	0.08000	8.5940	10.191	Oxygen, the mean of four trials.
	1.2841	0.10917	0.08262	8.5940	10.069	
Tippecanoe	1.2794	0.58367	0.01830	8.4085	10.289	
Midlothian, (screened)	1.3223	-	0.05688	8.7066	10.085	
Sidney	1.1382	0.89374	0.04585	8.1520	10.229	
	1.4340	0.43785	0.05875	7.8221	9.752	
Pictou, (from N. Y.)	0.9419	0.38558	0.06189	8.8059	10.145	
	1.0356	0.41986	0.07197	8.6658	10.193	
	1.1033	0.47511	0.07808	8.3207	9.977	

TABLE CXCIV—PART VII.

Designation of coal.	Data, by observation.														Relations of the chief products of combustion.					
															Water.				Carbonic acid collected.	
	Number of trial.	Date of experiment.	Condition of air plates.	Condition of damper—inches open.	Time drawing commenced.	Time occupied in drawing, in minutes.	Barometer, in inches, corrected for temperature of mercury at 60° Fahrenheit.	Temperature of air at mercurial bath, in degrees Fahrenheit.	Difference of temperature between escaping gases and air entering below ash pit—degrees Fahrenheit.	Dew point of air entering below ash pit, in degrees Fahrenheit.	Cubic inches of air taken into jar at observed temp. and pressure.	Weight of water collected, in grains.	Weight of carbonic acid collected, in grains.	Condensation, by phosphorus, in 100 volumes of gas in jar.	Grains of, in 100 cubic inches of atmospheric air, at dew point.	Grains of, derived from combustion.	Bulk of oxygen in, from combustion, in cubic inches.	Grains of hydrogen in, from combustion.	Cubic inches at standard temperature and pressure.	Grains of carbon in.
					h. m.															
Liverpool -	1	Aug. 25	Open.	8	1.18 p. m.	30.0	30.085	85.0	226.0	70.9	100	1.27	5.23	12.500	.469	0.7579	2.3180	.0842	11.026	1.4487
	2	" 26	Closed.	8	11.29 a. m.	27.0	30.087	87.5	255.0	74.1	100	1.07	5.81	8.992	.520	0.4948	1.5020	.0549	12.298	1.5094
	4	" 29	Open.	8	11.06 a. m.	36.5	30.138	84.0	267.0	74.9	100	1.09	6.19	9.688	.533	0.4356	1.3240	.0484	13.097	1.7146
Scotch -	1	Aug. 19	Closed.	8	0.11 p. m.	22.0	29.916	88.0	197.0	74.4	100	1.00	5.34	12.500	.525	0.4256	1.2930	.0473	11.299	1.4792
	2	" 21	Open.	8	0.59 p. m.	26.0	30.006	78.0	233.0	71.4	100	0.82	6.16	13.495	.479	0.2817	0.8561	.0313	13.034	1.7063
	4	" 23	Closed.	8	11.20 a. m.	31.0	30.008	77.5	257.0	70.0	100	0.74	5.79	13.125	.459	0.1816	0.5518	.0202	12.250	1.6688
Cannelton -	1	Nov. 7	Closed.	8	0.01 p. m.	46.0	29.950	43.0	260.0	35.5	100	0.99	7.40	5.000	.153	0.3183	2.4870	.0909	15.657	2.0498
	2	" 8	Open.	8	1.19 p. m.	45.0	30.109	47.0	232.5	26.4	100	1.42	7.38	7.708	.112	1.2960	3.9380	.1440	15.615	2.0443
Pine wood -	-	Nov. 18	Closed.	8	11.20 a. m.	49.5	30.039	63.5	234.5	48.8	100	1.62	4.80	12.500	.236	1.3667	4.1530	.1519	10.156	1.3290
		" 18	Closed.	8	1.16 p. m.	45.0	29.982	66.0	250.0	44.5	100	2.32	4.72	10.000	.305	2.1084	6.8920	.2337	9.967	1.3074

TABLE CXCIV—PART VII—Continued.

Designation of coal.	Relations of the chief products of combustion.						Deductions relative to heating power of fuel.							
	Nitrogen, at standard temperature and pressure, in cubic inches.	Oxygen in gases of jar, at standard temperature and pressure, in cubic inches.	Total of dry gases collected, including carbonic acid, in cubic inches.	Ratio to total bulk of dry gases, per cent. of the—			Grains of raw coal, equivalent to the carbon and hydrogen collected.	Atmospheric air, at standard temperature and pressure.				Pounds of water, equivalent in specific heat to the dry gases from one pound of fuel.	Water of combustion from one pound of fuel, in pounds.	Hygrometric moisture in the air required for one pound of fuel, in pounds.
				Carbonic acid.	Oxygen.	Sum of carbonic acid and oxygen.		Weight of, equivalent to the dry gases, in grains.	Bulk of, required for one lb. of fuel, in cubic feet.	Pounds of, required for one pound of fuel.	Pounds of, equal in specific heat to dry gases from one pound of fuel.			
Liverpool - -	84.139	12.020	107.185	10.287	11.214	21.501	1.62484	33.2400	267.23	20.458	21.023	5.611	0.46645	0.33175
	87.158	8.612	108.063	11.376	7.970	19.346	1.76471	33.5122	248.05	18.990	19.572	5.224	0 28010	0.28247
	87.147	9.348	109.592	11.951	8.530	20.481	1.86612	33.9864	237.90	18.212	18.798	5.017	0.23342	0.32439
Scotch - -	83.271	11.896	106.466	10.613	11.173	21.786	1.71125	33.0170	252.08	19.294	19.845	5.297	0.24971	0.34322
	83.931	13.094	110.059	11.843	11.897	23.740	2.00760	34.1312	222.08	17.001	17.544	4.683	0.14082	0.27065
	84.363	12.745	109.358	11.201	11.656	22.857	1.90070	33.9139	233.07	17.843	18.381	4.917	0.09554	0.27196
Cannelton - -	97.724	5.131	118.512	13.212	4.330	17.541	2 29479	36.7526	209.21	16.016	16.586	4.427	0.35659	0.07625
	94.752	7.913	118.280	13.202	6.690	19.892	2.31131	36.6807	207.30	15.870	16.434	4.386	0.56072	0.05583
Pine wood -	87.093	12.443	109.691	9.250	11.343	20.603	1.54216	34.0171	288.14	22.068	22.608	6.034	0 88628	0.16665
	89.029	9.893	108.908	9.170	9.083	18.253	1.60486	33.7743	274.90	21.046	21.564	5.755	1.31065	0.14063

TABLE CXCIV—Part VII—Continued.

Designation of coal.	Deductions relative to heating power of fuel. Pounds of steam from water, at 212°, to 1 lb. of fuel, equivalent to heat imparted to I.—Escaping gases.	II.—Water of combustion.	III.—Hygrometric moisture of the air.	IV.—Water evaporated from boiler.	Total calculated evaporative power to 1 of fuel, in steam from 212°.	Remarks.
Liverpool	1.2312	0.56880	0.07059	8.5546	10.425	
	1.2933	0.34945	0.08231	7.9038	9.628	Kept fire smoky whilst drawing gases.
	1.3006	0.29304	0.08409	8.0595	9.738	
Scotch	1.0130	0.31313	0.06564	7.4763	8.868	Gases to jar passed through hot oxide of copper, as well as other tests.
	1.0593	0.17206	0.06122	7.3059	8.598	
	1.2269	0.11938	0.06786	6.5129	7.927	
Cannelton	1.1175	0.44661	0.01925	6.8275	8.410	Gas puts out flame, and extinguishes ignited charcoal.
	0.9901	0.68729	0.01260	7.8543	9.544	Trial for oxygen, thrice repeated with similar results; gas entirely incombustible.
Pine wood	1.3738	1.08800	0.03840	4.6922	7.192	
	1.3970	1.62877	0.03413	4.6922	7.752	

Remarks on the preceding table.

The last column shows that the lowest result from any given coal was generally obtained when the combustion was conducted with a damper partly closed. The want of a free access of air, the stifling effect of retaining the products of combustion near the fire, and the increased quantity of smoke produced in such cases, are sufficient indications of the source of this inferiority.

From the columns under "*ratio to total bulk of dry gases, of carbonic acid and oxygen*," it is found that the average per centage of those two materials, and their sum, for the several classes of coals, was as follows, viz:

(1.) Of the anthracite class by	22	analyses, the *carb. acid*	was	9.443;	*oxygen*,	12.094;	*sum*,	21.537
(2.) Maryland free-burning	10	"	"	10.819	"	10.284	"	21.103
(3.) Pennsylvania do.	9	"	"	9.951	"	10.572	"	20.523
(4.) Virginia bituminous	16	"	"	9.564	"	11.298	"	20.862
(5.) Foreign bituminous	11	"	"	10.927	"	9.886	"	20.813
(6.) Cannelton bituminous	2	"	"	13 207	"	5.510	"	18.717
(7.) Pine wood	2	"	"	9.214	"	10.213	"	19.427

In several of these cases, the sum of the oxygen and carbonic acid is almost identical with the proportion in which oxygen is found in the atmosphere. Thus, Nos. 2, 3, 4, and 5, give a mean of 10.315 of carbonic acid, 10.510 of oxygen. An *excess* may probably be referred, in some instances, to the existence of carbonic acid in the coal, in the state of carbonates; and a *deficiency* to the production of much *water of combustion*, as in cases of the highly bituminous coals and of pine wood.

TABLE CXCV.

Evaporative power of the heat expended on the products of combustion.

Names of coals.	Per centage of evaporative power expended on the products of combustion.	Average per centage expended by each class of coals.	Names of coals.	Per centage of evaporative power expended on the products of combustion.	Average per centage expended by each class of coals.
Beaver Meadow (slope No. 3)	10.74		Barr's Deep Run	22.05	
Forest Improvement	13.83		Midlothian (900 feet shaft)	13.94	
Peach Mountain	10.89		Creek Company's coal	19.95	
Beaver Meadow (slope No. 5)	14.91		Chesterfield Mining Company	23.81	
Lehigh	26.93		Midlothian (new shaft)	15.08	
Lackawanna	10.20		Tippecanoe	18.28	
Natural coke	14.68		Midlothian (screened)	13.67	
Coke of Midlothian coal	12.15				18.11
		14.27	Sidney	20.05	
New York and Maryland Mining Company	15.40		Pictou	14.93	
Neff's (Cumberland)	18.38		Liverpool	17.70	
Atkinson & Templeman's	15.63		Scotch	16.14	
Easby's "Coal-in-Store"	15.93		Cannelton (Indiana)	18.23	
Easby & Smith's	8.96				17.41
Dauphin and Susquehanna	12.54		Pine wood	37.20	
Blossburg	14.15				
Lycoming Creek	15.09				
Quin's Run	11.37				
		14.16			

The preceding table is derived from the numbers in the latter columns of table CXCIV, and gives the differences between the average *total* evaporative powers for each kind of coal found by the last column of that table, and the steam-generating power displayed by the boiler, as exhibited in the column immediately preceding.

Heating power, as tested in making chains.

Nothing more than a very general approximation could be expected from this and similar methods of testing the relative strength of coals.

The same workman would not, probably, in every instance, make the same number of links with the same number of pounds of coal.

A given coal, tried at two different periods, might, with a little more or a little less care and economy of time, give results considerably different from each other.

The relation, however, between the steam-generating and the chain-making power of several of those coals between which considerable differences in constitution are known to exist, will be abundantly evident from inspection of the table.

Thus, between the Scotch and the Liverpool, and between the latter and the New York and Maryland Mining Company's, this relation becomes apparent.

It will be seen that three different sizes of ch
manufacture at the different periods at which these
They can, however, be all reduced to the same siz
a common standard sample of coal, which was use
Thus, Atkinson & Templeman's coal made 18 li
in diameter, and 8 links of another chain $1\frac{1}{4}$ inch
in each case of 60 pounds of coal. Midlothian
found adequate to the making of 14 links of $1\frac{1}{4}$-inc
ginia coals (viz: Crouch & Snead's, Creek Com
Mining Company's) having a mean evaporating
with the Midlothian "new shaft," put in 9 links o

Admitting their heating power when tried on chain to be the same as that of the "new shaft;" then, in making chain $1\frac{1}{4}$ inch in diameter, they would have been capable of making each 14 links of that size.

A decided general confirmation of the relative heating power of the coals, as deduced from evaporation, is afforded by the comparisons in the second and fifth columns of the following table. Thus—

			Steam.	*Links of chain.*
Four samples, viz:	Scotch, Cannelton, Picton, and Liverpool,	gave	7.635	11.25
Five samples, viz:	Crouch & Snead's, Creek Company's, Midlothian, (new shaft,) Chesterfield, and Dauphin and Susquehanna,	gave	8.769	14.00
Four samples, viz:	Newcastle, Blossburg, Quin's Run, and Midlothian, (900 feet shaft,)	gave	9.308	16.41
Four samples, viz:	Neff's, Atkinson & Templeman's, Barr's, and New York and Maryland Mining Company,	gave	9.671	19.00

For reasons above stated, and from the smallness of the quantity of coal used, the individual samples could hardly be expected to present fewer or less important discrepancies than are to be found in the table.

TABLE CXCVI.

Relative heating powers of different bituminous coals, as tested in making chain cable, compared with their evaporative powers.

Designation of coals.	Pounds of steam at 212° produced by 1 pound of coal.	Size of links—diameter, in inches.	Number of links made by 60 pounds of coal.	Deduced number of links of $1\frac{15}{16}$ inch in diameter by 60 pounds of coal.
Scotch	6.946	$1\frac{3}{8}$	10	10
Pictou (New York)	8.412	$1\frac{3}{8}$	11	11
Liverpool	7.842	$1\frac{3}{8}$	13	13
Midlothian (new shaft)	8.750	$1\frac{3}{8}$	14	14
Newcastle	8.656	$1\frac{3}{8}$	15	15
Atkinson & Templeman	10.699	$1\frac{3}{8}$	18	18
New York and Maryland Mining Comp'y	10.259	$1\frac{3}{8}$	20	20
Crouch & Snead	8.345	$1\frac{5}{8}$	9	14
Creek Company	8.416	$1\frac{5}{8}$	9	14
Chesterfield Mining Company	8.998	$1\frac{5}{8}$	9	14
Dauphin and Susquehanna	9.340	$1\frac{5}{8}$	9	14
Blossburg	9.724	$1\frac{5}{8}$	10	$15\frac{5}{9}$
Quin's Run	10.270	$1\frac{5}{8}$	11	$17\frac{1}{9}$
Cannelton (Indiana)	7.340	$1\frac{15}{16}$	5	11
Forks of Jennings's Run (Maryland)	–	$1\frac{15}{16}$	8	18
Midlothian (900 feet shaft)	8.584	$1\frac{15}{16}$	8	18
Neff's Cumberland	9.442	$1\frac{15}{16}$	8	18
Atkinson & Templeman	10.699	$1\frac{15}{16}$	8	18
Barr's Deep Run	9.018	$1\frac{15}{16}$	9	20

On the relative reductive powers of different classes of coals, as demonstrated by the experiments with oxide of lead.

The general result of experiments on 37 varieties of coal, tested after the manner of M. Berthier, may be exhibited by collecting into one view the four average results derived from the several classes of coals. The mean ratio of *fixed* to volatile combustible matter of each class is added, affording the means of judging approximately how far the volatile constituent affects the reductive power. The weight of oxygen given up by the lead, reduced by 1 part of combustible matter in the coal assayed, is calculated from the known composition of litharge. Had the combustible matter been pure carbon, and the product only carbonic acid, the oxygen would have been 2.66 parts to 1 of combustible. This, it will be seen, is only *approached* by the anthracites, and is farther and farther receded from by the bituminous coals, in proportion as their bituminousness increases. To the series of averages of my own experiments, I annex a similar series of the results given by M. Baudin, some of which have already been separately cited.

TABLE CXCVII.

Average reductive powers of American and foreign coals, as tested by litharge.

No. of samples furnishing the average.	Origin and nature of the coals assayed.	Evaporative power of the combustible matter.	Lead reduced by 1 of combustible matter, by experiment.	Ratio of fixed to 1 of volatile combustible.	Oxygen given up by the lead to 1 of combustible matter.
	1. COALS ASSAYED DURING THESE RESEARCHES.				
8	7 Pennsylvania anthracites and 1 sample of natural coke of Virginia - - - - -	10.587	32.517	23.891	2.5402
11	Maryland and Pennsylvania free burning coals -	10.877	31.786	4.908	2.4499
10	Virginia bituminous coals - - -	9.523	28.194	2.054	2.1765
8	Foreign and western highly bituminous coals -	8.710	27.740	1.955	2.1413
	2. FRENCH COALS ASSAYED BY M. BAUDIN.				
3	French anthracites, viz: Charbonnier, Messeix, and Chambled - - - - -	-	33.520	6.566	2.5876
3	2 free-burning coals of La Combelle, and 1 of Les Barthes, (Garnéire de 3 pieds) - -	-	32.040	3.477	2.4734
3	Bituminous coals of Langeac, Champlaix, and Madie - - - - - - -	-	29.830	2.155	2.3028
3	Highly bituminous coals of Ammenat, Néris, and Bert - - - - - -	-	27.586	1.446	2.1295

The French anthracites had obviously a much larger proportion of volatile matter than the American. They correspond in this respect very nearly with the natural coke of Virginia, of which the ratio of fixed to volatile combustible is 6.269. The average result in lead obtained by M. Baudin for the four classes of coals is about 2.2 per cent. higher than that given by my trials of analogous classes. This I attribute to a probable slight admixture of red oxide with the protoxide of lead which I employed. Though procured from a house of high celebrity for dealing in pure chemicals, its complexion led to the suspicion of a slight excess of oxygen in its composition. As, however, the same kind of litharge was used for all the samples of coal, the purpose of these comparative trials is equally well answered as if it had been chemically pure.

In some of the ultimate analyses of coals already reported may be found evidences, that the lead-reducing power depends (as the foregoing table indicates) on the carbon constituent, and not on the other elements. Thus the analysis of Cambria county coal of Pennsylvania proved its combustible matter to contain 91.955 per cent. of carbon, and experiment showed its lead-reducing power to be 31.464. Again, ultimate analysis showed Clover Hill coal of Virginia to have in its combustible matter 83.393 per cent. of carbon, and the trial by litharge proved the reductive power of the same combustible matter to be 28.527. Now, to *compute* the reductive power of Clover Hill combustible matter from its carbon, we have

TABLE CXCIX.—*Dew points, from the observations of dry and wet*

Temp. of air.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
100° -	98.8	97.7	96.6	95.4	94.2	93.0	91.8	90.6	89.4	88.1	86.8	85.5	84.2	82.9
99 -	97.8	96.7	95.5	94.3	93.1	91.9	90.7	89.5	88.3	87.0	85.7	84.4	83.1	81.6
98 -	96.8	95.7	94.5	93.3	92.1	90.9	89.7	88.5	87.2	85.9	84.6	83.3	82.0	80.7
97 -	95.8	94.6	93.4	92.2	91.0	89.8	88.6	87.4	86.1	84.8	83.5	82.2	80.9	79.6
96 -	94.8	93.6	92.4	91.2	90.0	88.8	87.6	86.3	85.1	83.8	82.5	81.2	79.8	78.4
95 -	93.8	92.6	91.4	90.2	89.0	87.8	86.5	85.3	84.0	82.7	81.4	80.1	78.7	77.3
94 -	92.8	91.6	90.4	89.2	88.0	86.7	85.5	84.2	82.9	81.6	80.3	78.9	77.5	76.1
93 -	91.8	90.6	89.4	88.2	87.0	85.7	84.4	83.1	81.8	80.5	79.2	77.8	76.4	75.0
92 -	90.8	89.6	88.4	87.2	85.9	84.6	83.3	82.0	80.7	79.4	78.0	76.6	75.2	73.8
91 -	89.7	88.5	87.3	86.1	84.9	83.6	82.3	81.0	79.7	78.3	76.9	75.5	74.1	72.7
90 -	88.7	87.5	86.3	85.1	83.8	82.5	81.2	79.9	78.6	77.2	75.8	74.4	73.0	71.5
89 -	87.7	86.5	85.3	81.0	82.7	81.4	80.1	78.8	77.4	76.0	74.6	73.2	71.8	70.3
88 -	86.7	85.5	84.3	83.0	81.7	80.4	79.1	77.7	76.3	74.9	73.5	72.1	70.6	69.1
87 -	85.7	84.5	83.2	81.9	80.6	79.3	78.0	76.6	75.2	73.8	72.4	70.9	69.4	67.9
86 -	84.7	83.5	82.2	80.9	79.6	78.2	76.9	75.5	74.1	72.7	71.2	69.7	68.2	66.6
85 -	83.7	82.4	81.1	79.8	78.5	77.2	75.8	74.4	73.0	71.5	70.0	68.5	67.0	65.4
84 -	82.7	81.4	80.1	78.8	77.5	76.1	74.7	73.3	71.8	70.4	68.9	67.3	65.7	64.1
83 -	81.7	80.4	79.1	77.8	76.4	75.0	73.6	72.2	70.7	69.2	67.7	66.1	64.5	62.8
82 -	80.7	79.4	78.1	76.7	75.3	73.9	72.5	71.0	69.6	68.1	66.5	64.9	63.2	61.5
81 -	79.7	78.3	77.0	75.6	74.2	72.8	71.4	70.0	68.4	66.9	66.3	63.7	62.0	60.3
80 -	78.6	77.3	76.0	74.6	73.2	71.7	70.3	68.8	67.2	65.7	64.1	62.4	60.7	58.9
79 -	77.6	76.3	75.0	73.5	72.1	70.7	69.2	67.6	66.1	64.5	62.8	61.1	59.4	57.6
78 -	76.6	75.3	73.9	72.5	71.0	69.5	68.0	66.5	65.0	63.3	61.6	59.8	58.1	56.2
77 -	75.6	74.2	72.8	71.4	69.9	68.4	66.9	65.3	63.7	62.1	60.3	58.5	56.7	54.8
76 -	74.6	73.2	71.8	70.3	68.9	67.3	65.8	64.2	62.5	60.8	59.1	57.2	55.3	53.4
75 -	73.6	72.2	70.7	69.2	67.7	66.2	64.6	63.0	61.3	59.5	57.7	55.9	54.0	52.0
74 -	72.6	71.1	69.7	68.2	66.6	65.1	63.4	61.8	60.1	58.3	56.4	54.5	52.5	50.4
73 -	71.5	70.1	68.6	67.1	65.5	64.0	62.3	60.6	58.8	57.0	55.1	53.1	51.1	49.0
72 -	70.5	69.1	67.5	66.0	64.4	62.8	61.1	59.3	57.5	55.7	53.7	51.7	49.6	47.3
71 -	69.5	68.0	66.5	64.9	63.3	61.6	59.9	58.1	56.2	54.4	52.4	50.3	48.1	45.7
70 -	68.5	67.0	65.4	63.8	62.2	60.5	58.7	56.9	55.0	53.0	51.0	48.8	46.5	44.1
69 -	67.4	66.0	64.3	62.7	61.0	59.3	57.5	55.6	53.7	51.6	49.5	47.3	44.9	42.4
68 -	66.4	64.9	63.2	61.6	59.9	58.1	56.3	54.3	52.3	50.2	48.0	45.7	43.2	40.5
67 -	65.4	63.8	62.2	60.5	58.7	56.9	55.0	53.0	51.0	48.8	46.5	44.1	41.5	38.8
66 -	64.4	62.7	61.1	59.3	57.5	55.7	53.7	51.7	49.6	47.3	45.0	42.4	39.7	36.8
65 -	63.3	61.7	60.0	58.2	56.4	54.5	52.5	50.4	48.2	45.8	43.4	40.7	37.9	34.8
64 -	62.3	60.6	58.9	57.1	55.2	53.2	51.2	49.0	46.7	44.3	41.7	39.0	36.0	32.7
63 -	61.3	59.6	57.8	55.8	54.0	52.0	49.8	47.6	45.1	42.7	40.1	37.1	34.0	30.5
62 -	60.3	58.5	56.7	54.8	52.8	50.7	48.5	46.2	43.7	41.1	38.3	35.2	31.9	28.2
61 -	59.2	57.4	55.5	53.6	51.5	49.4	47.1	44.7	42.2	39.4	36.4	33.2	29.7	25.7
60 -	58.2	56.3	54.4	52.4	50.3	48.1	45.7	43.2	40.6	37.7	34.6	31.1	27.3	23.0
59 -	57.2	55.3	53.3	51.2	49.1	46.8	44.3	41.7	39.0	35.9	32.6	28.9	24.8	20.1
58 -	56.1	54.2	52.2	50.0	47.8	45.4	42.9	40.1	37.2	34.0	30.5	26.6	22.1	17.0
57 -	55.1	53.1	51.0	48.8	46.5	44.0	41.4	38.5	35.5	32.1	28.3	24.1	19.2	13.5
56 -	54.0	52.0	49.8	47.6	45.2	42.6	39.8	36.8	33.6	30.0	26.0	21.4	16.1	
55 -	53.0	50.8	48.6	46.3	43.8	41.1	38.2	35.1	31.8	27.8	23.4	18.4	12.4	
54 -	51.9	49.7	47.5	45.0	42.4	39.6	36.6	33.3	29.7	25.6	20.8	15.3	8.5	
53 -	50.9	48.6	46.2	43.8	41.1	38.1	34.8	31.3	27.4	23.0	17.8	11.5	3.7	
52 -	49.8	47.5	45.1	42.4	39.6	36.6	33.2	29.7	25.3	20.5	14.8	7.8	— 1.4	
51 -	48.8	46.4	43.8	41.1	38.2	35.0	31.4	27.4	22.9	17.7	11.3	3.3		
50 -	47.7	45.2	42.6	39.7	36.6	33.3	29.5	25.3	20.4	14.7	7.4	— 2.0		
49 -	46.6	44.1	41.3	38.4	35.1	31.6	27.5	23.0	17.7	11.2	2.9			
48 -	45.5	42.9	40.0	37.0	33.5	29.7	25.5	20.6	14.7	7.3	— 2.4			
47 -	44.4	41.7	38.7	35.5	31.9	27.9	23.3	17.9	11.4	3.1				
46 -	43.4	40.5	37.4	34.0	30.1	25.7	20.8	14.8	7.4	— 2.6				
45 -	42.2	39.3	36.1	32.5	28.4	23.9	18.5	12.0	3.6					
44 -	41.1	38.1	34.7	30.9	26.2	21.7	15.8	8.5	— 1.2					
43 -	40.1	36.8	33.2	29.3	24.7	19.4	12.9	4.6	— 7.0					
42 -	38.9	35.6	31.8	27.6	22.7	16.9	9.7	0.2						
41 -	37.8	34.3	30.3	25.8	20.6	14.3	6.2	— 5.0						
40 -	36.7	33.0	28.8	23.9	18.1	11.4	2.2	— 11.0						

bulb thermometers.—(Excess of temperature of the dry over the moist bulb.)

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
81.6	80.3	78.9	77.5	76.1	74.7	73.2	71.7	70.2	68.6	67.0	65.4	63.7	61.9	60.1	58.8
80.5	79.2	77.8	76.4	75.0	73.5	72.0	70.5	68.9	67.3	66.7	64 0	62.3	60.5	58.6	56.7
79.4	78.0	76.6	75.2	73.7	72.4	70.7	69.2	67.6	66 0	64.3	62.6	60.8	59.0	57.1	55.1
78.2	76.8	75.4	74.0	72 5	71.0	69.5	67.9	66.3	64.6	62.9	61.2	59.4	57.5	55 4	53.5
77.1	75.7	74.2	72.8	71.3	69.8	68.2	66 6	64.9	63.2	61.5	59 7	57.8	55 9	54.0	51.9
75.9	74.5	73.0	71.5	70.0	68.5	66.9	65.3	63.6	61.9	60.1	58 3	56.4	54 4	52.3	
74.7	73.3	71.8	70.3	68 8	67.2	65.6	63.9	62.2	60 4	58.6	56.7	54.7	52 7	50 5	
73.6	72.1	70.6	69.1	67.5	65.9	64.2	62.5	60.8	59.0	57.1	55.2	53.2	51.0	48.8	
72.4	70.9	69.4	67.8	66.2	64.6	62 9	61 2	59.4	57.5	55.6	53.6	51.5	49.3		
71.2	69.7	68 1	66.5	64.9	63.2	61.5	59.7	57.9	56.0	54.0	52.0	49.8	47.5		
70.0	68.4	66.8	65.2	63.6	61.9	60.1	58.3	56.4	54 4	52.4	50.3	48 0	45.6		
68.8	67.2	64.3	63 4	62.2	60.5	58.7	56.9	54 9	52.9	50.8	48.5	46.2			
67.5	65.9	63.0	62.6	60.9	59.1	57.2	55.3	53.3	51.2	49.0	46.7	44 3			
66.3	64 7	61.6	61.3	59.5	57.7	55.8	53.8	51.7	49 6	47.3	44.9	42.4			
65.0	63.3	60.3	59.9	58.1	56.2	54.2	52.2	50.1	47.8	45.5	43.0				
63.7	62.0	59.0	58.5	56.6	54.7	52.7	50.6	48.4	46.1	43.6	41.0				
62.4	60.7	57.5	57.1	55.2	53.2	51.1	48.9	46.6	44 2	41.6	38.9				
61.1	59.4	56.1	55.6	53.7	51.6	49 5	47.2	44.8	42.3	39.6					
59.8	58.0	54.7	54.2	52.1	50.0	47 8	45.4	43 0	40.3	37.4					
58.5	56.6	53.2	52.7	50.6	48.4	46.1	43.6	41.0	38.2	35.2					
57.1	55.2	51.7	51.1	49.0	46.7	44.3	41.7	39.0	36.0						
56.7	53.7	50.1	49.6	47.3	45 0	42.4	39.7	36.8	33.7						
54.2	52.2	48.5	46.2	45.6	43.1	40.4	37.6	34.6	31.2						
52.8	50.7	46.9	44.5	43.8	41.2	38.4	35.4	32 2							
51.3	49.2	45.2	42.7	42.0	39 2	36.3	33.1	29.7							
49.8	47.6	43.5	40.8	40.1	37.2	34.1	30 7	27.0							
48.2	46.0	41.6	39.0	38.1	35.0	31.7	28.1								
46.6	44.2	39.8	36.9	36.0	32.8	29.2	25.3								
45.0	42.5	37.8	34.8	33.8	30.4	26.5	22.3								
43.3	40.6	35.8	32.5	31.4	27.8	23.7									
41.5	38.7	33.6	30 2	29.0	25.0	20.5									
39.7	36.8	31.4	27.7	26.3	22.0	17.1									
37.8	34.7	29.0	25.0	23.5	18.8										
35.8	32.5	26.4	22.1	20.4	15.1										
33.7	30.2	23.6	18.8	17.0											
31.5	27.8	20.6	15.3	13.2											
29.2	25.2	17.3	11.4												
27.6	22.3	13.7													
24.0	19 3	9.6													
21.2	15.9														
18.1	12.2														
14.6	7.9														
10.8															
6.4															

TABLE CC.—*General sypnoptical table of*

Designation of coal.		Specific gravity.	Weight per cubic foot, calculated from specific gravity.	Weight per cubic foot, by experiment.	Ratio of actual to calculated weight.	Cubic feet of space required to stow a ton.	Volatile combustible matter, in 100 parts.	Fixed carbon, in 100 parts.
Beaver Meadow, slope No. 3, -	Pa.	1.610	100.645	54.93	0.546	40.78	2.38	88.94
Beaver Meadow, slope No. 5, -	Pa.	1.551	96.93	56.19	0.580	39.86	2.66	91.47
Forest Improvement, - -	Pa.	1,477	92.31	53.66	0.581	41.75	3.07	90.75
Peach Mountain, - -	Pa.	1,464	91.51	53.79	0.588	41.64	2.96	89.02
Lehigh, - - -	Pa.	1.590	99.39	55.32	0.557	40.50	5.28	89.15
Lackawanna, - - -	Pa.	1,421	88.84	48 89	0.550	45.82	3.91	87.74
Lyken's Valley, - -	Pa.	1.389	86.82	48.56	0.559	46.13	6.88	83.84
Beaver Meadow, (navy yard,) -	Pa.	-	-	55.08	-	40.65	-	-
Natural coke of Virginia, -	Va.	1.323	82.70	46.64	0.564	48.03	12.44	75.08
Coke of Midlothian coal, -	Va.	-	-	32.70	-	68.50	-	-
Coke of Neff's (Cumberland) coal,	Md.	-	-	31.57	-	70.95	-	-
Mixture, one-fifth Cumberland and four-fifths Beaver Meadow - -		-	-	54.29	-	41.26	-	-
Mixture, one-fifth Cumberland and four-fifths Beaver Meadow - -		-	-	54.51	-	41.09	-	-
New York and Maryland Mining Company's, - - -	Md.	1.431	89.44	53.70	0.600	41.71	12.31	73.50
Neff's Cumberland, - -	Md.	1.337	83.28	54.29	0.652	41.26	12.67	74.53
Easby's "Coal-in-Store," -	Md.	1.307	81.69	53.47	0.655	41.90	14.98	76.26
Atkinson & Templeman's, -	Md.	1.313	82.09	52.92	0.645	42.33	15.58	76.69
Easby & Smith's, - -	Md.	1.332	83.26	51.16	0.614	43.78	15.52	74.29
Cumberland, (navy yard,) -	Md.	1.414	88.40	53.29	0.602	42.04	14.87	70.85
Dauphin and Susquehanna, -	Pa.	1.443	90.19	50.54	0.560	44.32	13.82	74.24
Blossburg, - - -	Pa.	1.324	82.73	53.05	0.641	42.22	14.78	73.11
Lycoming Creek, - -	Pa.	1.388	86.74	55.38	0.638	40.45	13.84	71.53
Quin's Run, - - -	Pa.	1.331	83.22	50.34	0.605	44.50	17 97	72.79
Karthaus, - - -	Pa.	1.284	80.22	52.54	0.655	42.63	19.58	73.77
Cambria County, - -	Pa.	1.407	87.91	53.46	0.608	41.90	20.52	69.37
Barr's Deep Run - -	Va.	1.382	86.41	53 17	0 615	42.13	19.78	67.96
Crouch & Snead's, - -	Va.	1.451	90.71	53.59	0.591	41.80	24.38	59.98
Midlothian, (900 feet shaft,) -	Va.	1.437	87.50	50.52	0.577	44.34	27.28	61.08
Creek Company's coal, - -	Va.	1.319	82.48	46.50	0.564	48.17	32.47	60.30
Clover Hill, - - -	Va.	1.285	80.36	45.49	0.566	49.25	32.21	56.83
Chesterfield Mining Company's, -	Va.	1.289	80.57	45.55	0.565	49.18	32.63	58.79
Midlothian, (average,) - -	Va.	1.294	80.90	54.04	0.568	41.45	29.86	53.01
Tippecanoe, - - -	Va.	1.346	84.14	45.10	0.536	49.67	34.54	54.62
Midlothian, ("new shaft,") -	Va.	1.325	82.82	47.90	0.581	46.76	35.77	56.40
Midlothian, (screened,) - -	Va.	1.283	80.21	45.72	0.570	48.99	34.70	54.06
Midlothian, (navy yard,) -	Va.	1.390	86 86	54.47	0.627	41.13	29.12	56.11
Pictou, (from New York,) -	N.S.	1,318	82.35	53.55	0.650	41.83	27.83	56.98
Sidney, - - -	N.S.	1.338	83.66	47.44	0.567	47.22	23.81	67.57
Pictou, (Cunard's,) - -	N.S.	1.325	82.83	49.25	0.595	45.48	25.97	60.74
Liverpool, - - -	Eng.	1.262	78.89	47.88	0.607	46.78	39.96	54.90
Newcastle, - - -	Eng.	1.257	78.54	50.82	0.647	44.08	35.83	57.00
Scotch, - - -	Scotland.	1.519	94.95	51.09	0.538	43.84	39.19	48.81
Pittsburg, - - -	Pa.	1.252	78.37	46.81	0.598	47.85	36.76	54.93
Cannelton, - - -	Ind.	1.273	79.54	47.65	0.599	47.01	33.99	58.44
Dry pine wood - - - -		-	-	21.01	-	106.62	-	-

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TABLE CCI.—*Ranks of coals, according to their several practical characters.*

Rank first.	Names of coals, arranged in the order of their RELATIVE WEIGHTS.	Pounds per cubic foot, by experiment.	Relative weights.	Rank second.	Names, in the order of RAPIDITY OF IGNITION.	Time required to bring the boiler to steady action, in hours.	Relative rapidities of ignition.
1	Beaver Meadow, slope No. 5	56.19	1.000	1	Cannelton, (Indiana) -	0.50	1.000
2	Lycoming Creek - -	55.37	.985	2	Quin's Run - -	0.75	.667
3	Lehigh - - -	55.32	.984	3	Dauphin and Susquehanna -	[illegible]	.602
4	Beaver Meadow, (navy yard)	55.08	[illegible]	4	Newcastle - - -	0.84	[illegible]
5	Beaver Meadow, slope No. 3	54.92	.977	5	Blossburg - - -	0.84	.595
6	Mixture, 1-5th Cumberland and 4-5ths Beaver Meadow	54.51	.970	6	Pictou, (Cunard's) -	0.85	[illegible]
				7	Liverpool - - -	0.86	.581
7	Midlothian, (navy yard) -	54.46	.969	8	Midlothian, "new shaft" -	0.90	.556
8	Mixture, 1-5th Midlothian and 4-5ths Beaver Meadow	54.29	.966	9	Pictou, (New York) -	0.94	.532
				10	Scotch - - -	0.96	.521
9	Neff's Cumberland -	54.28	.966	11	Athinson & Templeman's -	0.99	.505
10	Midlothian, (average) -	54.05	.962	12	Crouch & Snead's - -	1.16	.431
11	Peach Mountain - -	53.82	.958	13	Chesterfield Mining Company's - -	1.17	.427
12	New York and Maryland Mining Company's -	53.70	.956	14	Coke of Neff's Cumberland	1.17	.427
13	Forest Improvement -	53.66	.955	15	Sidney - - -	1.18	.424
14	Crouch & Snead's - -	53.57	.953	16	Midlothian, (screened) -	1.29	.388
15	Pictou, (New York) -	53.55	.953	17	New York and Maryland Mining Company's -	1.33	.376
16	Easby's "Coal-in-Store" -	53.47	.952				
17	Cambria County - -	53.46	.951	18	Tippecanoe - -	1.33	.376
18	Cumberland, (navy yard) -	53.29	.948	19	Midlothian, (900 feet shaft)	1.38	.362
19	Barr's Deep Run - -	53.17	.946	20	Midlothian, (average) -	1.52	.329
20	Blossburg - - -	53.05	.944	21	Barr's Deep Run - -	1.52	.329
21	Atkinson & Templeman's -	52.92	.942	22	Easby & Smith's - -	1.52	[illegible]
22	K[illegible] - -	52.64	.936	23	Creek Company's - -	1.67	.290
23	E[illegible] - -	51.16	.910	24	Neff's Cumberland -	1.68	.298
24	S[illegible] - -	51.09	.909	25	Lycoming Creek - -	1.72	.291
25	N[illegible] - -	50.82	.904	26	Natural coke - -	1.74	[illegible]
26	D[illegible]ehanna	50.54	.900	27	Easby's "Coal in-Store" -	1.75	.286
27	M[illegible]et shaft)	50.52	.899	28	Karthaus - - -	1.87	.267
28	Q[illegible] - -	50.33	.896	29	Clover Hill - -	1.93	.259
29	P[illegible] -	49.25	.876	30	Coke of Midlothian coal -	2.00	.250
30	L[illegible] - -	48.86	.870	31	Cambria county coal -	2.00	.250
[illegible]	L[illegible] - -	48.56	[illegible]	32	Mixture, 1-5th Cumberland and 4-5ths Beaver Meadow	2.25	.222
[illegible]	M[illegible]shaft" -	47.90	.853				
33	L[illegible] - -	47.88	.852	33	Beaver Meadow, slope No. 5	2.42	.207
34	C[illegible]e) -	47.65	.848	34	Lyken's Valley - -	2.63	.194
35	Sidney - - -	47.44	.844	35	Lackawanna - -	[illegible]	.187
36	Pittsburg - - -	46.81	.833	36	Mixture, 1-5th Midlothian and 4-5ths Beaver Meadow	3.21	.156
37	Natural coke - -	46.63	.830				
38	Creek Company's - -	46.49	.827	37	Lehigh - - -	3.27	.153
[illegible]	Midlothian, (screened) -	45.73	.814	38	Forest Improvement -	3.32	[illegible]
40	Chesterfield Mining Company's - - -	45.66	.811	39	Peach Mountain - -	3.53	.142
				40	Beaver Meadow, slope No. 3	[illegible]	.130
41	Clover Hill - -	45.48	.809	41	Beaver Meadow, (navy yard)	[illegible]	.099
42	Tippecanoe - -	45.10	.803				
43	Coke of Midlothian coal -	32.70	.582				
44	Coke of Neff's Cumberland	31.57	.562				
45	Dry pine wood - -	21.00	.374				

TABLE CCI—Continued.

Rank third.	Names, in the order of COMPLETENESS OF COMBUSTION.	Pounds of unburnt coke on the grate after each trial.	Relative completeness of combustion.	Rank fourth.	Names, in the order of EVAPORATIVE POWER UNDER EQUAL WEIGHTS.	Pounds of steam produced from water at 212°, by 1 lb. of fuel.	Relative evaporative power for equal weights.
1	Pictou, (Cunard's) -	3.7	1.000	1	Atkinson & Templeman's -	10 70	1.000
2	Atkinson & Templeman's -	5.1	.725	2	Quin's Run - -	10.27	.960
3	Easby & Smith's - -	5.3	.698	3	Peach Mountain - -	10 11	.945
4	Pictou, (New York) -	5.7	.649	4	Forest Improvement -	10.06	.940
5	Scotch - - -	5.7	.649	5	Easby's "Coal-in-Store" -	10.02	.936
6	Midlothian, (900 feet shaft)	5.9	.627	6	Easby & Smith's - -	9.96	.931
7	Sidney - - -	5.9	.627	7	Beaver Meadow, slope No. 5	9.88	.923
8	Crouch & Snead's - -	6.0	.617	8	Lackawanna -	9.79	.915
9	Neff's Cumberland -	6.1	.607	9	New York and Maryland		
10	Cannelton, (Ia.) - -	6.4	.578		Mining Company's -	9.78	.914
11	Barr's Deep Run - -	6.4	.578	10	Blossburg - - -	9.72	.908
12	Midlothian, (average) -	6.4	.578	11	Lyken's Valley - -	9.46	.884
13	Mixture, 1-5th Midlothian			12	Neff's Cumberland -	9.44	.882
	and 4-5ths Beaver Meadow	9.5	.389	13	Dauphin and Susquehanna	9.34	.873
14	Pittsburg - - -	9.9	.374	14	Cambria County - -	9.24	.863
15	New York and Maryland			15	Beaver Meadow, slope No. 3	9.21	.861
	Mining Company's -	10.1	.366	16	Mixture, 1-5th Cumberland		
16	Chesterfield Mining Co.'s -	10.5	.352		and 4-5ths Beaver Meadow	9.18	.858
17	Creek Company's - -	10.5	.352	17	Karthaus - - -	9.09	.850
18	Newcastle - - -	10.7	.346	18	Beaver Meadow, (navy yard)	9.08	.849
19	Liverpool - - -	11.1	.333	19	Barr's Deep Run - -	9.02	.843
20	Tippecanoe - -	11.2	.330	20	Chesterfield Mining Co.'s -	9.00	.841
21	Clover Hill - -	11.5	.322	21	Coke of Neff's Cumberland	8.99	.840
22	Cumberland, (navy yard) -	13.5	.274	22	Midlothian, (screened) -	8.94	.836
23	Blossburg - - -	13.7	.270	23	Lehigh - - -	8.93	.835
24	Quin's Run - -	14.7	.252	24	Lycoming Creek - -	8.91	.833
25	Midlothian, (screened) -	14.8	.250	25	Mixture, 1-5th Midlothian		
26	Cambria County - -	14.8	.250		and 4 5ths Beaver Meadow	8.86	.828
27	Mixture, 1-5th Cumberland			26	Midlothian, "new shaft" -	8.75	.818
	and 4-5ths Beaver Meadow	16 0	.231	27	Newcastle - - -	8.66	.809
28	Midlothian, "new shaft" -	17.1	.216	28	Coke of Midlothian coal -	8.63	.80
29	Lyken's Valley - -	18.0	.206	29	Midlothian, (900 feet shaft)	8.58	.8 .143
30	Easby's "Coal-in-Store" -	18.2	.203	30	Pictou, (Cunard's) -	8.48	.142
31	Dauphin and Susquehanna -	23.7	.156	31	Natural coke - -	8.47	.136
32	Peach Mountain - -	26.6	.139	32	Creek Company's - -	8.42	.136
33	Lehigh - - -	36.1	.102	33	Pictou, (New York) -	8.41	.136
34	Forest Improvement -	40.2	.092	34	Crouch & Snead's -	8.34	.133
35	Midlothian, (navy yard) -	43.2	.086	35	Midlothian, (average) -	8.29	.126
36	Coke of Neff's Cumberland	43.7	.085	36	Pittsburg - - -	8.20	
37	Lycoming Creek - -	46.2	.080	37	Sidney - - -	7.99	.122
38	Karthaus - - -	52.5	.070	38	Liverpool - - -	7.84	.113
39	Coke of Midlothian coal -	53.2	.069	39	Tippecanoe - -	7.75	.112
40	Lackawanna - -	57.2	.065	40	Clover Hill - -	7.67	
41	Natural coke - -	60.9	.061	41	Cannelton, (Ia.) - -	7.34	.111
42	Beaver Meadow, slope No. 5	61.2	.060	42	Scotch - - -	6.95	.107
43	Beaver Meadow, (navy yard)	107.1	.034	43	Dry pine wood - -	4.69	.098
44	Beaver Meadow, slope No. 3	112.4	.033				.097
							.093
							.068
							.057

TABLE CCI—Continued.

Rank fifth.	Names of coals, in the order of EVAPORATIVE POWER UNDER EQUAL BULKS.	Pounds of steam from 212°, produced by 1 cubic ft. of each coal.	Relative evaporative power for equal bulks of coal.
1	Atkinson & Templeman's	566.2	1.000
2	Beaver Meadow, slope No. 5	556.1	.982
3	Peach Mountain	545.7	.964
4	Forest Improvement	540.8	.955
5	Easby's "Coal in Store"	535 6	.946
6	New York and Maryland Mining Company	524.8	.927
7	Quin's Run	517.0	.913
8	Blossburg	515.9	.911
9	Neff's Cumberland	512.7	.906
10	Easby & Smith's	511.1	.903
11	Beaver Meadow, slope No. 3	505.5	.893
12	Beaver Meadow, (navy yard)	500.0	.883
13	Mixture, 1-5th Cumberland and 4-5ths Beaver Meadow	498.5	.880
14	Lehigh	494.0	.872
15	Lycoming Creek	493.3	.871
16	Cambria County	486.9	.860
17	Mixture, 1-5th Midlot'n and 4-5ths Beaver Meadow	481.1	.850
18	Barr's Deep Run	478.7	.845
19	Lackawanna	477.7	.844
20	Karthaus	477.4	.843
21	Dauphin and Susquehanna	472.8	.835
22	Lyken's Valley	459.7	.812
23	Pictou, (New York)	450.6	.796
24	Midlothian, average	448.5	.792
25	Crouch & Snead's	445.0	.786
26	Newcastle	439.6	.776
27	Midlothian, (900 feet shaft)	433.7	.766
28	Midlothian, "new shaft"	418.6	.739
29	Pictou, (Cunard's)	417.9	.738
30	Chesterfield Mining Co.'s	410.9	.726
31	Midlothian, (screened)	408.7	.722
32	Natural coke	395.3	.698
33	Creek Company's	391.8	.692
34	Pittsburg	384.1	.678
35	Sidney	378.9	.669
36	Liverpool	375.4	.663
37	Scotch	353.8	.625
38	Tippecanoe	350.2	.618
39	Cannelton, (Ia.)	348.8	.616
40	Clover Hill	347.4	.614
41	Coke of Neff's Cumberland	284.0	.502
42	Coke of Midlothian coal	282.6	.499
43	Dry pine wood	98.6	.175

Rank sixth.	Names, in the order of the EVAPORATIVE POWER OF COMBUSTIBLE MATTER.	Pounds of steam from 212° to 1 of combustible matter.	Relative evaporation by equal weight of combustible matter.
1	Atkinson & Templeman's	11.62	1.000
2	Quin's Run	11.27	.970
3	New York and Maryland Mining Company	11.21	.965
4	Dauphin and Susquehanna	11.17	.961
5	Easby & Smith's	11.03	.949
6	Blossburg	10.96	.943
7	Easby's "Coal-in-Store"	10.93	.941
8	Peach Mountain	10.87	.935
9	Forest Improvement	10.81	.930
10	Lyken's Valley	10.79	.929
11	Lackawanna	10.76	.926
12	Lycoming Creek	10.72	.923
13	Neff's Cumberland	10.60	.912
14	Beaver Meadow, slope No. 5	10.59	.911
15	Beaver Meadow, slope No. 3	10 46	.900
16	Natural coke	10.39	.894
17	Coke of Neff's Cumberland	10 38	.893
18	Coke of Midlothian	10.34	.890
19	Cambria County	10 24	.883
20	Barr's Deep Run	10.14	.873
21	Mixture, 1-5th Cumberland and 4-5ths Beaver Meadow	10.00	.861
22	Midlothian, (screened)	9.97	.858
23	Chesterfield Mining Co.'s	9.90	.852
24	Karthaus	9.89	.851
25	Beaver Meadow, (navy yard)	9.88	.850
26	Midlothian, "new shaft"	9 75	.839
27	Midlothian, (average)	9.74	.838
28	Crouch & Snead's	9.74	.838
29	Mixture, 1-5th Midlot'n and 4-5ths Beaver Meadow	9.72	.836
30	Pictou, (New York)	9.71	.836
31	Pictou, (Cunard's)	9.65	.830
32	Lehigh	9.63	.829
33	Midlothian, (900 feet shaft)	9.61	.827
34	Creek Company's	9.21	.793
35	Newcastle	9.18	.790
36	Pittsburg	8.94	.769
37	Clover Hill	8.59	.739
38	Tippecanoe	8.58	.738
39	Sidney	8 50	.731
40	Liverpool	8.25	.710
41	Cannelton, (Ia.)	7.73	.666
42	Scotch	7.72	.664
43	Dry pine wood	4.71	.405

TABLE CCI—Continued.

Rank seventh.	Names, in the order of freedom from waste in burning.	Per centage of total waste, in clinker and ashes.	Relative freedom from waste.
1	Dry pine wood	0.307	16.417
2	Liverpool	5.04	1.000
3	Cannelton, (Indiana)	5.12	.984
4	Newcastle	5.68	.887
5	Sidney	6.01	.839
6	Beaver Meadow, slope No. 5	6.74	.748
7	Peach Mountain	6.97	.723
8	Forest Improvement	6.97	.723
9	Lehigh	7.22	.698
10	Karthaus	7.89	.639
11	Atkinson & Templeman's	7.96	.633
12	Beaver Meadow, (navy yard)	8.10	.622
13	Mixture, 1 5th Cumberland and 4 5ths Beaver Meadow	8.18	.616
14	Pittsburg	8.25	.611
15	Easby's "Coal in-Store"	8 38	.601
16	Creek Company's	8.64	.583
17	Mixture, 1-5th Midlothian and 4-5ths Beaver Meadow	8.88	.568
18	Lackawanna	8.93	.564
19	Quin's Run	8.94	.564
20	Chesterfield Mining Company's	9.07	.556
21	Easby & Smith's	9.69	.520
22	Tippecanoe	9.72	.519
23	Cambria County	9.75	.517
24	Scotch	10.10	.499
25	Midlothian, "new shaft"	10.26	.491
26	Midlothian, (screened)	10.27	.491
27	Clover Hill	10.60	.475
28	Midlothian, (900 feet shaft)	10.70	.471
29	Neff's Cumberland	10.96	.460
30	Barr's Deep Run	11.07	.455
31	Blossburg	11.20	.450
32	Beaver Meadow, slope No. 3	11.96	.421
33	Pictou, (Cunard's)	12.06	.418
34	Lyken's Valley	12.24	.412
35	New York and Maryland Mining Company's	12.71	.397
36	Coke of Neff's Cumberland	13.34	.378
37	Pictou, (New York)	13.37	.377
38	Crouch & Snead's	14.31	.351
39	Cumberland, (navy yard)	14.53	.347
40	Midlothian, (average)	14.83	.340
41	Dauphin and Susquehanna	16.36	.308
42	Coke of Midlothian coal	16.54	.305
43	Lycoming Creek	16.92	.298
44	Natural coke	18.46	.273

Rank eighth.	Names, in the order of freedom from tendency to form clinker.	Per centage of clinker alone, to coal burned.	Relative freedom from clinker.
1	Beaver Meadow, slope No. 5	0.60	1.000
2	Forest Improvement	0.81	.741
3	Pittsburg	0.94	.639
4	Beaver Meadow, slope No. 3	1.01	.594
5	Lehigh	1.08	.555
6	Lackawanna	1.24	.484
7	Quin's Run	1.31	.458
8	Easby's "Coal-in-Store"	1.33	.451
9	Beaver Meadow, (navy yard)	1.40	.429
10	Cannelton, (Indiana)	1.64	.366
11	Liverpool	1.86	.323
12	Atkinson & Templeman's	2.13	.282
13	Sidney	2.25	.267
14	Cumberland, (navy yard)	2.29	.202
15	Peach Mountain	3.03	.198
16	Easby & Smith's	3.05	.197
17	Mixture, 1-5th Cumberland and 4-5ths Beaver Meadow	3.09	.194
18	Newcastle	3.14	.191
19	Lycoming Creek	3.26	.184
20	Midlothian, (screened)	3.33	.180
21	Blossburg	3.40	.176
22	Cambria County	3.48	.172
23	Dauphin and Susquehanna	3.50	.171
24	Coke of Neff's Cumberland	3.55	.169
25	Karthaus	3.66	.164
26	Clover Hill	3.86	.155
27	Tippecanoe	4.03	.149
28	Chesterfield Mining Company's	4.19	.143
29	Midlothian, "new shaft"	4.21	.142
30	Lyken's Valley	4.40	.136
31	Creek Company's	4.42	.136
32	Midlothian, (navy yard)	4.42	.136
33	Neff's Cumberland	4.53	.133
34	Barr's Deep Run	4.75	.126
35	Mixture, 1-5th Midlothian and 4-5ths Beaver Meadow	4.91	.122
36	Natural coke	5.31	.113
37	Crouch & Snead's	5.37	.112
38	New York and Maryland Mining Company's	5.43	.111
39	Scotch	5.63	.107
40	Pictou, (New York)	6.13	.098
41	Pictou, (Cunard's)	6.19	.097
42	Midlothian, (900 feet shaft)	6.47	.093
43	Midlothian, (average)	8.82	.068
44	Coke of Midlothian coal	10.51	.057

TABLE CCI—Continued.

Rank ninth.	Names of coals, in the order of MAXIMUM EVAPORATIVE POWER UNDER GIVEN BULKS.	Highest No. of lbs. of steam from 212°, produced by one cubic foot of coal, in any one experiment.	Relative maximum evaporative power.	Rank tenth.	Names, in the order of MAXIMUM RAPIDITY OF EVAPORATION.	Greatest evaporation per hour, in cubic feet of water.	Relative maximum rapidity of action.
1	Peach Mountain	581.3	1.000	1	Chesterfield Mining Company's	19.33	1.000
2	Forest Improvement	577.5	.994	2	Blossburg	19.28	.996
3	Atkinson & Templeman's	573.3	.986	3	Creek Company's	18.98	.981
4	Beaver Meadow, slope No. 5	572.9	.986	4	Pictou, (Cunard's)	17.96	.928
5	New York and Maryland Mining Company	546.9	.941	5	Peach Mountain	17.44	.901
6	Easby's "Coal-in Store"	535.6	.921	6	Easby & Smith's	17.14	.886
7	Neff's Cumberland	532.3	.916	7	Neff's Cumberland	16.96	.877
8	Beaver Meadow, slope No. 3	526.5	.906	8	Tippecanoe	16.94	.875
9	Blossburg	522.6	.899	9	Cambria County	16.77	.867
10	Quin's Run	518.1	.892	10	Liverpool	16.59	.857
11	Easby & Smith's	516.7	.889	11	Scotch	16.42	.847
12	Mixture, 1-5th Cumberland and 4-5ths Beaver Meadow	515.5	.887	12	Karthaus	16.31	.843
13	Lehigh	515.4	.887	13	Atkinson & Templeman's	16.06	.828
14	Karthaus	512.9	.882	14	Newcastle	16.01	.827
15	Cambria County	509.1	.876	15	Midlothian, (900 feet shaft)	15.93	.823
16	Lycoming Creek	505.2	.869	16	Cannelton, (Indiana)	15.55	.804
17	Beaver Meadow, (navy yard)	502.6	.865	17	Coke of Midlothian coal	15.50	.801
18	Lackawanna	493.0	848	18	Lehigh	15.33	.792
19	Lyken's Valley	489.2	.842	19	Forest Improvement	15.28	.790
20	Barr's Deep Run	488.7	.841	20	Midlothian, "new shaft"	15.12	.781
21	Dauphin and Susquehanna	486.4	.837	21	Lackawanna	15.08	.779
22	Mixture, 1-5th Midlothian and 4-5ths Beaver Meadow	482.3	.830	22	Coke of Neff's Cumberland	14.91	.770
23	Pictou, (New York)	478.7	.824	23	Dauphin and Susquehanna	14.82	.766
24	Crouch & Snead's	463.2	.797	24	Sidney	14.79	.764
25	Midlothian, (average)	461.63	.794	25	Pictou, (New York)	14.54	.751
26	Newcastle	453.9	.781	26	Midlothian, screened	14.12	.730
27	Midlothian, (900 feet shaft)	446.2	.768	27	Quin's Run	14.05	.726
28	Midlothian, screened	438.4	.754	28	Beaver Meadow, slope No. 5	13.96	.722
29	Creek Company's	435.0	.748	29	Barr's Deep Run	13.93	.720
30	Pictou, (Cunard's)	427.9	.736	30	Lyken's Valley	13.75	.711
31	Midlothian, "new shaft"	424.2	.730	31	Lycoming Creek	13.66	.706
32	Chesterfield Mining Company's	422.8	.727	32	Mixed, Beaver Meadow and Cumberland	13.56	.701
33	Liverpool	411.2	.707	33	Beaver Meadow, slope No. 3	13.47	.696
34	Natural coke	407.9	.702	34	Natural coke	13.31	.688
35	Tippecanoe	391.8	.674	35	Mixed, Beaver Meadow and Midlothian	13.22	.683
36	Sidney	386.1	.664	36	New York and Maryland Mining Company	13.10	.677
37	Pittsburg	384.1	.661	37	Easby's "Coal-in-Store"	12.73	.658
38	Scotch	369.1	.635	38	Crouch & Snead's	12.29	.635
39	Cannelton, (Indiana)	360.0	.619	39	Midlothian, (average)	12.16	.628
40	Clover Hill	359.3	.618	40	Beaver Meadow, (navy yard)	11.14	.576
41	Coke of Neff's Cumberland	284.0	.488	41	Clover Hill	10.48	.542
42	Coke of Midlothian coal	282.5	.486	42	Pittsburg	10.00	.517
43	Dry pine wood	98.6	.170				

The tables last presented, containing, *first*, a general synoptical view of the character and efficiency of the several coals, and, *secondly*, a number of distinct classifications in reference to different characters considered to be of the most practical importance, and based, in every instance, on the numerical results of experiment, will, I trust, be found highly serviceable in guiding those whose duty it may be to make choice of fuel for the naval or other public service, to the selection of such as will answer the specific object for which they may be procured.

In applying the table of ranks, it will readily be understood that, where any given rank is determined by a series of numbers (on the right of the names) *increasing* downwards, the number at the top is used as a dividend, to be divided by each of those below it; and that, on the contrary, where the rank is decided by a series *diminishing* downwards, the number at the top becomes a divisor for each of those below it: and in both cases, the quotients become series of decimals, expressive of the relative values of the coals against which they stand, as compared with that occupying the head of the list taken as unity.

If an equal importance could be attached to every one of the qualities of coals which form the bases of the ten ranks above given, then the *sum* of the ratios or relative values found in the last columns would, for any sample, give nearly its true relative value in the market. Such equality does not, however, exist. Nor is it easy to assign the exact relative weight or importance of the several qualities indicated. For different purposes they must be differently estimated. Thus, when sold by weight and used on shore, the weight per cubic foot, as given in the first rank, is a point of little moment. Space for stowage is easily obtained. But in steam navigation, bulk, as well as weight, demand attention; and a difference of *twenty per cent.*, which experiment shows to exist between the highest and the lowest average weight of a cubic foot of different coals, assumes a value of no little magnitude.

For the purposes of steam navigation, therefore, the rank most important to be considered is the fifth, in which the names of coals stand in the order of their *evaporative* power, under given bulks. This is obviously true, since, if other things be equal, the length of a voyage must depend on the amount of evaporative power afforded by the fuel which can be stowed in the bunkers of a steamer, always of limited capacity.

With the scale of values under equal bulks must, however, be combined those in the eighth and tenth ranks, the former showing the *relative freedom from clinker*, and the latter the *maximum rapidity of action* of the several samples. The *rapidity of ignition*, given in the second rank, is of inferior importance, but may deserve some consideration where short voyages, frequent stoppages, and a prompt commencement of action, are demanded.

In relation to the 10th rank—that founded on *maximum rapidity of evaporation*—it should be observed, that, though in this, as in all other cases, the actually observed rate of action is inserted in the table, yet that the few samples which were in every experiment burned with a chimney only 41 feet high, instead of 63 feet, (which was its height after the 27th of May,) ought to have the numbers showing the evaporation per hour in cubic feet increased nearly in proportion to the increased height of chimney. Samples numbered 32, 35, 39, 40, and 41, in that rank, are those to which this remark more particularly applies.

As every sample of coal has been allowed a fair opportunity to exhibit its own distinctive character, it would be useless to attempt to substitute for the results of practical experiments, on such a scale as is here presented, any mere *opinions* or conjectures derived from observations made at random, with no standards of time, weight, or magnitude; or even any *theoretical conclusions* drawn from tests, however skilfully applied, merely to single hand specimens. It has been my aim in all these researches to avoid matters extraneous to the experiments themselves and to their legitimate interpretation. It has not been deemed expedient to swell this report by the introduction of matters not within my own cognizance.*

The numerous certificates and declarations which, either in the form of reports, or other published articles, have from time to time been put forth in regard to certain coals, may in some instances be entitled to consideration, as evidences of their superior worth; in others, of a commendable industry and energy on the part of the proprietors, agents, directors of companies, and others interested in their development and use. If these commendations have not in every instance been entirely justified, it is perhaps to be taken as a new evidence that in this, as in many other important matters, those merits which have not been the most loudly proclaimed may, upon due examination, be found among the most estimable and the most enduring.

It will not fail to be remarked, that the justly celebrated foreign bituminous coals of Newcastle, Liverpool, Scotland, Pictou, and Sidney—coals which constitute the present reliance of the great lines of Atlantic steamers—are fully equalled, or rather surpassed in strength, by the analogous coals of eastern Virginia; that they are decidedly surpassed by all the free-burning coals of Maryland and Pennsylvania; and that an equally decided advantage in steam-generating power is enjoyed by the anthracites over the foreign coals tried, whether we consider them under equal weights or equal bulks.

Experiment appears to demonstrate that, for the purposes of *rapid* evaporation, and for the production of illuminating gas, the coal of Indiana, though neither very heavy nor very durable, is inferior to none of the highly bituminous class to which it belongs; since in heating power, and in freedom from impurity, it surpasses the splint and cannel coal of Scotland.

Apprized of the strong desire felt by the department to be in possession of the results of these inquiries, I have spared no effort to bring them to an early conclusion, though satisfied that in doing so the researches cannot be considered complete.

One of the important points which it would be desirable further to investigate, is the proportion of *sulphur;* which, it will be seen by the several synoptical tables, was only tested on single specimens, for a part of the series. This is a labor of time, which, for reasons already assigned, is unavoidably left incomplete.

Another point of practical importance is the composition of the earthy matter, or ashes, of each coal. On the investigation of this, it was not found practicable even to enter. It is of no inconsiderable interest, in relation to

* For an account of numerous results obtained by Dr. Dana, Mr. Francis, Mr. Hayes, and others, in relation to this subject, by means analogous to those which have been here employed, I would respectfully refer to a paper on the evaporative power of coals in the second Bulletin of the National Institute, (February, 1842,) page 165.

the metallurgic arts to which coal is applicable. In lieu of any researches on this subject upon the samples of coal here reported, I beg leave to add a series of analyses of this nature, which I made some years since. They are chiefly the ashes of anthracites. One happens, however, to have come from the same mines which furnished one of the samples of bituminous coal examined in this report.

TABLE CCII.

Composition and character of ashes from several varieties of coal.

Characters and ingredients of ashes.	Sugarloaf Company's anthracite, Hazle creek—1st specimen. Specific gravity 1.591.	Sugarloaf anthracite—2d specimen. Specific gravity 1.574.	Sugarloaf anthracite—3d specimen. Specific gravity 1.55.	Buck Mountain anthracite. Specific gravity 1.559.	Summit Coal Company's anthracite, head of Beaver creek—1st specimen. Specific gravity 1.613.	Summit Company's anthracite—2d specimen. Specific gravity 1.594.	Stevenson's Bluff anthracite, Beaver creek. Specific gravity 1.612.	Salem-vein anthracite, Pottsville. Specific gravity 1.569.	Quin's Run bituminous coal. Specific gravity 1.372.
Per centage of ashes in the coal -	4.83	8.73	2.242	3.079	5.01	4.00	3.71	6.75	6.80
Color - -	light buff.	reddish white.	white	reddish buff.	fawn	reddish gray.	fawn	brick red.	gray.
Silica in ashes, per ct.	53.603	45.105	43.68	45.60	54.50	50.25	50.05	50.00	76.00
Alumina - -	36.687	37.000	39.34	42.75	34 45	38.90	39.04	38.90	21.00
Peroxide of iron -	5.590	13.000	8.22	9.43	7.50	8.75	8.75	8.00	2.60
Lime - -	2.857	1.380	5.76	1.41	2.25	0.85	1.56	2.10	
Magnesia - -	1.076	2.430	3.00	0.33	1.30	1.25	1.30	0.90	
Oxide of manganese	0.186								
Loss, per cent. -	-	1.085	-	-	-	-	-	-	0.40
Sum - -	99.989	100.	100.	99.52	100.	100.	100.70	99.90	100.

I cannot by any means regard the *investigation of American coals* as an exhausted subject.

A glance at any good geological map of the United States, in which the coal fields are laid down, will show how exceedingly limited is the whole amount of space covered by the several detached coal troughs from which the samples here presented were derived, compared with the immense extent of that formation which covers western Pennsylvania and Virginia, eastern Ohio, the eastern part of Kentucky, a part of middle Tennessee, and an undefined portion of Alabama; and much more when compared with the vast tracts of coal country in Illinois, Iowa, Missouri, Arkansas, and a considerable portion of Michigan.

The surprising extension of steam navigation on the western rivers and the northwestern lakes, as well as on the gulf of Mexico and the adjacent seas, the increase of population, and the consequent clearing of woodlands,

all point significantly to a necessity which must be felt, at no distant day, to have recourse to mineral fuel for supplying this rapidly increasing demand.

To understand the relative strength and usefulness of the coals from the several parts of the three great western coal regions, requires that they be examined with no less care than has been applied to the limited spaces from which were derived the materials operated on during these experiments. It may be added, that the products of many coal districts *east* of the Allegany mountains are yet unexamined.

If in any case *knowledge is power*, it is pre-eminently so when it relates to a subject which constitutes the greatest element of power in the physical world, and in the present age of marvellous developments.

I cannot conclude this report without again bearing testimony to the efficient aid which the industry and intelligence of my principal assistant and co-laborator, Dr. Henry King, has rendered in carrying out my views in the arrangement and computation of many of the tables accompanying this report. To his perseverance, with that of another assistant, Mr. S. W. Hall, do I owe the application of the formulas which I had prepared for ascertaining the mean pressures of steam during every day's experimenting, and also of those for computing the table of experiments on the composition and heat-absorbing powers of the gases of the chimney. The labor of these and similar computations, even with all the aid which mathematical tables afford, is exceedingly arduous, and requires the utmost vigilance to avoid error. It is, perhaps, too much to hope that no inaccuracy whatever has occurred in their applications of these formulas, embracing, as they necessarily do, numerous classes of elements. But as every examiner of the work will have all the data before him, mere numerical errors, should such occur, can be readily discovered and corrected.*

In the hope that the results now offered for your acceptance will be found serviceable to the important arm of national defences committed to your charge, and to justify the favorable views of the enlightened and lamented statesman† under whose immediate auspices they were commenced, I have now the honor to submit them to your hands, with the assurance that I remain, with great respect, your obedient servant,

WALTER R. JOHNSON.

WASHINGTON, *June* 3, 1844.

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* It is due to two other assistants to state that the records of nearly all the observations on evaporative power were made by Mr. James W. Kendall, by whom also much aid was rendered in preparing the tables, and making the calculations necessary to form the deductions accompanying this report; and that the duties of superintending the supply of water during the experiments, the drying of samples of coal, of making observations on the temperature of water in the supplying reservoir, and of steam in the boiler, were committed to Captain Thomas S. Easton. The duties of both these assistants were performed with a zeal, constancy, and fidelity, meriting high approbation.

† The late Hon. Abel P. Upshur, then Secretary of the Navy.

INDEX.

☞ For convenient reference to the numerous samples of coal, to the distinct points of inquiry, to the various descriptions of apparatus, to the several modes of experimenting, and to the different classes of results, an index to this report has been deemed indispensable, and is herewith furnished.